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CONTENTS

Page

Street Lighting in a Large London Suburb, by Alan T. Durbridge - 263

The Economics of Four Industrial Lighting Installations, by S. T. Clark, W. Howe, M.I.E.E., F. Jones, G. W. S. Levey *(Member)* - - - - 279

Additions to the List of Members - - 317

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Street Lighting in a Large London Suburb

By ALAN T. DURBRIDGE

Summary

At the conclusion of the War in 1945 the Harrow Urban District Council (Middlesex) was faced with the much overdue task of providing efficient and modern public lighting throughout the district. The district (population 225,000) is mainly residential with a number of shopping areas. The paper describes the method adopted by the local authority in solving the problem and traces the progress to date of a "Five year plan." The financial aspect is also examined.

(1) Description of District

Harrow is perhaps best known for its famous School founded in 1571; at that time this village on the Hill was surrounded by prosperous farm lands although only 11 miles by road from the heart of London. Gradually, during the succeeding centuries, building development took place, until in the years after the First World War the phenomenal development of North-West London engulfed Harrow and beyond. Until April, 1934, the name of Harrow was a mere abbreviation for the township of Harrow-on-the-Hill. The Middlesex Review Order of 1934 brought about the complete reconstitution of Harrow, and the newly formed Urban District of Harrow included within its boundaries the old urban areas of Harrow and Wealdstone and the parishes of Pinner, Harrow Weald and the Stanmores. The area thus formed is now the largest Urban District in the country, both in acreage and population :—

Acreage :	Approx. 20 sq. miles
Population :	Approx. 225,000
Rateable Value :	£2,233,000

The district is almost wholly residential and is a "dormitory" of London. To transport thousands of workers daily to the Metropolis, it is served by eighteen railway stations.

(1.1) Geographical Survey

The district is some 11 miles north-west from London, with Wembley Borough to the south, the county boundary of Hertfordshire in the north, Hendon to the east and Ruislip-Northwood to the west. The southern half is densely populated; part of the northern sector is open country, remnants of common land, all now protected by inclusion in the "Green Belt." There are nine well defined shopping centres with smaller ones interspersed, but there is no real "Town Centre." Through traffic routes link the district with London and other major suburbs.

(1.2) Mileage of Roads and Traffic Conditions

The road system of the district comprises :—

Ministry of Transport Classified Roads	44 miles
Unclassified Roads	180 „
Total	224 miles

A recent census on traffic conditions at peak periods in the day revealed that a considerable use of the roads must be provided for, especially during the late after-

The author is District Manager, Harrow District of the Eastern Electricity Board. The manuscript of this paper was first received on December 29, 1953, and in revised form on March 4, 1954. The paper was presented at the Society's Summer Meeting, Southport, on May 19, 1954.

noon rush hour in the winter months when daylight has gone. Some typical traffic counts are given in Table 1.

Table 1

Peak Traffic, Vehicles per hour two-way

	Vehicles	Cycles
Kenton Road by Sheepcote Road	933	96
Station Road, Greenhill	847	321
Alexandra Avenue by Northolt Road	820	121
Lowlands Road	780	146

There are many other roads which have a traffic density of 500/600 vehicles per hour.

In addition to the vehicular traffic very large crowds of pedestrians occur twice daily during the peak hours at the railway stations. The number of omnibus services is regulated according to the importance of the station and adequate lighting is essential at these busy and dangerous spots.

(2) Lighting—Immediate Post War

At September, 1945, the area was lighted wholly by gas (two exceptions being 2 x 60-watt lanterns outside the house of the Headmaster of Harrow School). There were 7,179 columns, with nearly 1,400 lanterns burning all night, the remainder being extinguished at 1.0 a.m. (after the last train had left).

Neighbouring districts were already reinstating their pre-war installations most of which were more up-to-date than that at Harrow. This contrast produced very trying conditions for the road user who had to pass through the alternately well and poorly lighted districts. Further, the neighbouring districts had at that time a variety of methods of lighting.

There were several problems involved in modernising the lighting in Harrow

Table 2

Classification of Roads and Minimum Standards of Illumination

(*a*) Classification of Roads:

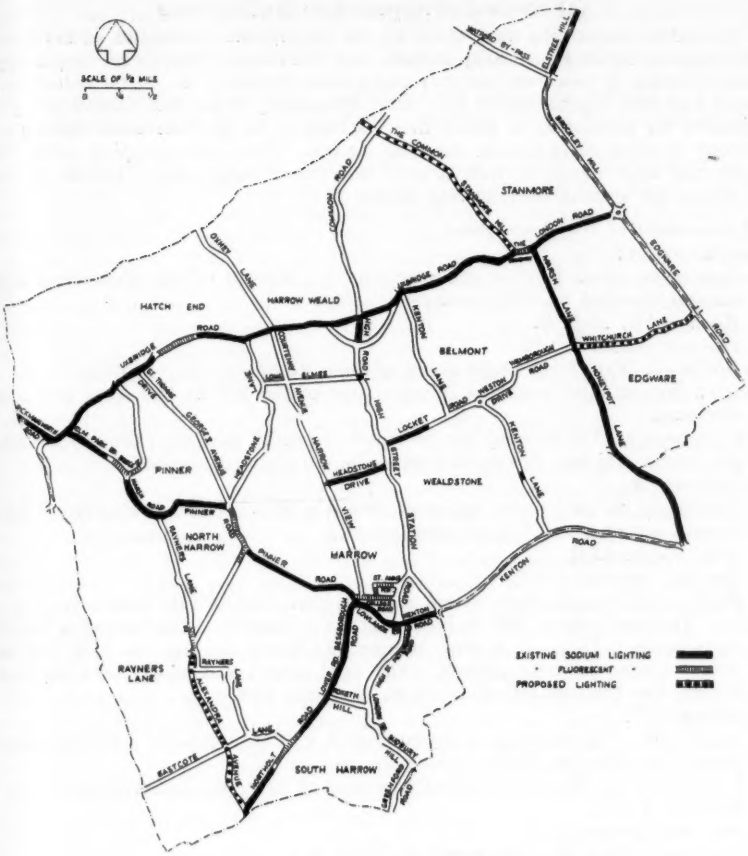
Group A.	Arterial and classified roads carrying a heavy volume of traffic.
Group B.	Residential roads acting as connecting links for traffic between main roads.
Group C.	Purely residential roads.

(*b*) Recommended Minimum Standards of Illumination:

	Lumens per 100 ft. linear.		
	Group A.	Group B.	Group C.
Harrow U.D.C. Conference	5,000	2,000	900
Ministry of Transport	3,000–8,000	600–2,500	—

Note: Group C was subsequently withdrawn and the Harrow Council adopted the following minimum standards:—

Group A	5,000 lumens
Group B	900 lumens



Plan showing the main roads in the Harrow U.D.C.

and in 1946 the Harrow Council called to conference its neighbours from Ealing, Hendon, Wembley and Ruislip-Northwood to hear their views and to agree in principle on the standardisation of lighting for the main traffic routes transversing their areas.

At this time, with the exception of certain boundary roads, the street lighting in Harrow was operated under agreement with the Gas, Light and Coke Co. This agreement having expired, the Council had to consider the question of a new agreement and obtain tenders from the appropriate Gas and Electricity Companies.

Between October, 1947, and January, 1949, two conferences were held with the neighbouring authorities. Certain standards were finally agreed regarding the grouping of the roads and the minimum illumination applicable to each. The method used to obtain the minimum standards of illumination was left for the decision of each local authority. The agreed standards reached are given in Table 2.

(3) Method of Approach to the Problems

Numerous inspections were made by the appropriate Committee of the Council of all types of lighting in nearby districts and elsewhere. There were ample opportunities afforded to view both mercury and sodium installations. In the meantime the Council had been approached by four firms specialising in the manufacture of lighting equipment for permission to install trial installations of six fluorescent lighting units to Group A standard in various shopping centres. Four such shopping centres were chosen and each equipped with a trial fluorescent installation. Details of these installations are given in the following section.

(3.1) Description of Trial Installations

Manufacturer A:

Installation of six lanterns equipped with 2 x 80-watt tubular fluorescent lamps; lanterns mounted on 25 ft. concrete columns.

Road width: 30-38 ft.

Spacing: About 110 ft.

Buildings: Vary from single storey to three storey—shops and offices.

Site: Straight and level and included one of the busiest bus stops and station entrances.

Performance: The lighting, though much improved over the existing four burner gas fittings, was not considered quite up to the required standard.

Manufacturer B:

Installation of six lanterns equipped with 4 x 80-watt tubular fluorescent lamps; lanterns mounted on 25 ft. concrete columns.

Road width: 45 ft.

Spacing: Approx. 110 ft.

Buildings: No uniformity—shops and flats over, with private houses.

Site: Included a bend and an important "T" junction at the fork of a long hill.

Performance: The lantern was unnecessarily heavy and did not look well on a rather slender concrete column. The light output was satisfactory but it was thought that the fourth lamp could be dispensed with.

Manufacturer C:

Installation of six lanterns equipped with 3 x 80-watt tubular fluorescent lamps; lanterns mounted on 25 ft. concrete columns.

Road width: 33 ft. with an island pavement of 20 ft. plus a service road 20 ft.

Spacing: 110 ft.

Site: Straight and level.

Buildings: Shops with flats over.

Performance: Regarded as satisfactory although the fitting called for a special head at the top of the column. The installation was equipped most unfortunately with a batch of faulty chokes which failed at intervals.

Manufacturer D:

Installation of six lanterns equipped with 3 x 80-watt tubular fluorescent lamps; lanterns mounted on 25 ft. concrete columns.

Road width: 33 ft. with 40 ft. wide pavement on one side, 15 ft. on the other.

Spacing: Approx. 100 ft.

Buildings: Shops with flats over—half three-storeyed, and half two-storeyed.

Site: Level with a very slight curve. The test site included the entrance to a very busy Tube station and bus station.

Performance: Not a very pleasing design of lantern, which was also found to be a dust trap with consequent reduction in efficiency of reflectors. The lighting of this busy traffic spot was, however, much improved and it was found that the accident rate—classed as a "black spot"—was much reduced.

General Notes on Trial Installations: Light control in all fittings was by specular

reflectors. All lanterns were fitted with acrylic plastic bowls hinged according to the manufacturer's design.

The opportunity was taken to try out concrete columns of various manufacture.

(3.2) Conclusions Reached from Trial Installations and Equipment Selected

The Council decided in April, 1949, that electricity should be adopted for street lighting.

As a result of the four trial installations it was decided to standardise on the three-lamp unit which gave a luminous output comparable to that from a 140-watt sodium lamp. It was further decided that reflectors in lanterns were unsatisfactory and that the control of light should be by means of refractors.

About that time, one of the manufacturers participating in the trials produced a greatly improved lantern embodying acrylic refractors sealed to the enclosing bowl, so dispensing with the need for reflectors. With the exception of a few additions to one or two of the trial installations the new refractor lantern was subsequently used for lighting the shopping areas.

Information had meanwhile been obtained regarding the equipment for sodium lighting. It was decided that for all sizes of sodium lamps, the lantern should be of the totally enclosed type with a one-piece light alloy die-cast canopy. Light control was to be by acrylic refractor plates cemented on the inside of the bowl. This construction prevents ingress of dirt to the prismatic surfaces. The light distribution is of the medium angle beam type. On fairly steep gradients side entry lanterns are used to obtain a uniform distribution of light on the road surface, otherwise the appearance of the top entry lantern is generally preferred.

The choice of material for columns and brackets was considered and it was recommended that reinforced concrete columns should be used, chiefly because they require little or no maintenance. Cast-iron and steel columns, on the other hand, require periodical painting. The aggregate specified was granite, the surface being ground to a smooth finish. All designs had to be approved by the Royal Fine Arts Commission—or later by the Council of Industrial Design.

An experiment was carried out to convert a few short cast-iron columns from gas to electricity by fitting a control box and swan-neck bracket on the top of the column. This method has been found to be costly because the absence of a door at the base of the column necessitates an extra length of service cable. It is cheaper to provide a new concrete column and recover part cost of the cast-iron column as a second-hand sale or as scrap.

(4) Final Policy

In August, 1949, the Council approved a five-year programme for converting the whole of the district to electricity, recommending that fluorescent lighting should be adopted for Group A roads and sodium lighting for Group B roads. The absence of colour distortion provided by the fluorescent lamp was considered to be a great advantage over mercury and sodium installations, particularly in main roads where there are shops. At that time the total cost of the complete scheme was estimated at £376,000. Owing to the severe restrictions in capital expenditure imposed by the Government at that time and also owing to the shortage of steel and other materials, the Ministry of Transport intimated that only a limited expenditure would be allowed each year on public street lighting.

The Ministry also pointed out that fluorescent lighting would be approved only for the principal shopping areas of the district. This was a disappointment to the Local Authority who were planning a first-class lighting service for the district. The capital cost, however, proved to be a very important factor and the Ministry's decision was accepted, although with the utmost reluctance. In view of this, the Council, in February, 1950, approved the First Year's Programme, estimated at £26,200, which

included the provision of 116 fluorescent lanterns in the principal shopping areas and 263 140-watt sodium lanterns in five miles of the Uxbridge Road traffic route from east to west. This scheme was submitted to the Ministry of Transport in June, 1950, and the work was completed in the autumn of 1951.

The Second Year's Programme, estimated at £30,000, included a further 450 140-watt sodium lanterns. This scheme was submitted to the Ministry of Transport in October, 1951, and completed in the autumn of 1953. Whilst the first- and second-year programmes were in progress, other street-lighting developments were taking place. New roads on housing estates were being equipped with 45/60-watt sodium lanterns. The opportunity was also taken to install 45/60 watt sodium lanterns in existing roads where widening and other improvements were being undertaken.

The Third Year's Programme, estimated at £21,600, comprising 270 140-watt sodium lanterns, was submitted to the Ministry of Transport in March, 1953, for which approval was granted in part for the erection of 200 lamps at a cost of £16,000; this work will be in hand shortly. Unless the sums allocated for expenditure on street lighting are substantially increased in the future, under present circumstances it is estimated that the work of improving the lighting of the remainder of the Group A roads in the district will not be completed until 1958.

The work of converting the 180 miles of unclassified roads to Group B standard will be carried out when the Group A roads have been relighted.

(4.1) Installation Design

There are not many straight roads in Harrow, and in consequence the number of lanterns installed on Group A roads per route mile is increased beyond that required when the normal spacing of 120 ft. is possible. In order to comply with the Ministry of Transport's recommendations for the lighting of bends, junctions and traffic roundabouts, there are many lanterns sited at between 80 and 90 ft. apart. In contrast to the 44 lanterns per mile required for normal spacing on straight roads, one important traffic route in Harrow completed recently necessitated an average of 57 lanterns per mile.

The preservation of natural amenities, for example certain types of trees, must be taken into account. At two points the lantern has been purposely left out of its proper position in order to avoid cutting back a particularly fine specimen tree. This was done without seriously upsetting the quality of the lighting.

The lighting of Group B roads depends very largely on the layout of the housing estates. It is important that all road junctions should have special treatment and, therefore, spacing will not necessarily be uniform.

Service roads fronting arterial and other through-traffic routes often require their own installation to Group B standard, should the Group A lighting be insufficient owing to the abnormal widths of pavement and verges.

(4.2) Exceptions to General Policy

It has been found expedient to provide 100-watt tungsten lamps for the following locations:—

(i) To fill gaps in the lighting of residential roads where there are already a number of existing gas lamps. At some future date it will be possible to convert these without inconvenience to 45/60-watt sodium lamps.

(ii) In footways and passages leading through spinneys or short cuts from one estate to another where there is a certain amount of wilful damage. It is less costly to replace a 100-watt lantern than its sodium counterpart.

(iii) In service roads at the rear of shops, etc. These roads are little used by the public and lanterns and columns are liable to be damaged by vehicles turning in a confined space.

(4.3) Treatment of " Black Spots " by Isolated Lamps

Four 45/60-watt sodium lanterns in positions recommended by the British Standard Code of Practice have been installed at a number of dangerous cross-road junctions in residential areas lit by gas. The orange-coloured light gives a clear warning to traffic of the presence of a road junction ahead.

The experiment has been very successful and will be extended as expenditure permits.

(4.4) Control of Supply

Over more than half of the district the Electricity Board possessed a " fifth core " or street lighting switch wire incorporated in the distribution cables; this enabled many lamps to be switched from a single time switch placed conveniently in a substation. The remainder of the lamps are at the moment independently time switched. With the return of a more stable and continuous electricity supply, synchronous time switches with solar dials can now be safely used.

Consideration may be given at some future date to the practicability and economics of introducing some form of group control to replace individual switching.

(5) Costs

The figures quoted in this section must be regarded as typical for the installations mentioned in this paper.

(5.1) Capital and Running Costs of a Fluorescent Installation

The capital cost in 1951 (date of most recent installation) of a 3/80 watt Group A fluorescent installation was £3,872 per mile. Assuming 44 columns per mile of straight road this is equivalent to £88 per column. It should be noted that this figure does not allow for the cost of removing redundant gas lamp, reinstatement of surfaces and contingencies such as alterations to cables, overhead telegraph wires, etc.

The running cost is around £12 per lantern per annum, again an inclusive figure for energy, maintenance, lamp replacement (on an all-night burning basis), cleaning (four times per annum) and scouting which, at the moment, is once every seven days.

(5.2) Capital and Running Costs for 140-watt Sodium Installation

The present day (December, 1953) cost of a 140-watt sodium installation is £2,992 per mile based on 44 columns per mile of straight road; this is equivalent to £68 per column.

The running cost is around £11 per lantern per annum based on the same operating and maintenance conditions as for the fluorescent lighting referred to above.

(5.3) Capital and Running Cost for 45/60-watt Group B Installation

The capital cost of a 45-watt sodium installation is £1,980, again based on 44 columns to the mile of straight road. This is equivalent to £45 per column. The 60-watt installation is only a few shillings more per column, representing the difference in the cost of the two lamps.

The running cost is approximately £6 14s. per annum for a 60-watt lantern and £6 4s. per annum for a 45-watt lantern, both calculated on an all-night basis. The maintenance conditions are the same as those outlined for the fluorescent installation described in Para. (5.1) above.

(6) Maintenance Experiences

It must be borne in mind that the very earliest sections of this relighting scheme were only commissioned in 1949. Indeed, the bulk has been in use only since mid-1952 and, therefore, experience gained so far is limited. Nevertheless, it is worth while to record what has occurred to date.

(6.1) Replacement of Lamps

The Council has made a contract with the Electricity Board, not only to supply the energy, but also to carry out full maintenance which includes lamp renewal. By arrangement, the Council provides the first lamp—in other words the Council hands over to the Board an installation complete in every way for commissioning on an agreed date.

Lamps are changed according to a routine schedule, the replacement intervals being determined by the declared lamp life and synchronised with the lantern cleaning rota.

Defective lamps which fail prematurely are replaced free of cost by the manufacturers. Lamps which are constantly the target for wilful damage become a charge to the Lighting Authority.

As is well known, fittings for sodium lamps should allow the lamp to be held with the cap about 2 deg. above the horizontal. If this is rigidly maintained then little or no trouble is experienced with premature failures or failure to "strike." Experience has clearly shown that considerable importance should be paid to the voltage at each individual lamp service terminal and full advantage taken of the adjustable tapping provided on the transformer. This is simple since all the auxiliaries are mounted in the base of the column.

Fluorescent lamps provide a trouble-free lighting source so long as the acrylic cover or bowl is close fitting and adequately screens the lamps from cold draughts.

The disposal of used lamps must be given attention. Fluorescent lamps should be broken up, whilst sodium lamps must be demolished under water before being removed as trader's refuse.

(6.2) Performance of Fittings

The fluorescent fittings, of which there are five different makes in commission, give little trouble. In one type of lantern, however, it is doubtful if the manufacturer paid sufficient attention to the correct drilling of the acrylic cover in relation to the fixing studs of the metal casting. As a result some covers have cracked into two or more pieces.

Although the experience gained so far is limited, the totally enclosed fitting used for the sodium installations has proved to be trouble-free. The interior remains remarkably clean.

It does appear that a simple device is warranted which would enable the erector to fix the fitting for the correct angle for sodium lamp burning. Although the columns when erected have a small back filling of concrete the clay soil responds to weather conditions and the column may be tilted out of the perpendicular.

Attention has had to be given to the adequate screening of lamps near railways. Cut-off fittings must be employed and, in some instances, it has been found necessary to paint the concrete bracket arm with a matt black paint before the railway signal engineer was satisfied.

Similarly, as Harrow is close to Northolt Airport, screening must be provided in certain parts of the district. The Air Ministry now permit the use of a modified form of cut-off lantern known as aero-screening which, while not completely cut off at the horizontal, would meet with the Air Navigation requirements in most cases and, what is important, gives satisfactory road lighting at normal spacings of the order of 120 ft., which is not so with completely cut-off lanterns. The installation in Eastcote Lane, South Harrow, now being planned will be equipped with this form of screening.

(6.3) Performance of Auxiliaries

Mention has already been made earlier in this paper of the failure of a number of auxiliaries associated with one of the trial fluorescent installations, but no further failures on such a scale have occurred. A new transformer may, however, break down on switching in for the first time. Most of the transformers are of the solid filled type. No trouble has been met with capacitors.

Experience has shown that bad radio interference from sodium lamps can come about and invariably the interference was found to be radiated by old-type asymmetrically wound leak transformers. Replacement by symmetrically wound transformers invariably eliminated the interference.

(6.4) Cleaning Required in a London Suburb

Although Harrow is some 11/12 miles from London, smoke pollution of the atmosphere is noticeable in the winter when thousands of domestic coal fires are in use. The bad "smog" of December, 1952, caused appreciable soiling of public lighting fittings, but this notorious "smog" was perhaps exceptional in the abnormal length of the bad conditions. Normally fittings, unless very close to railways, can be kept to a good standard of cleanliness by cleaning only four times per annum.

The use of one of the modern soapless detergents has been found to be very helpful in removing the grime, and assists in restoring the "gleam" or sparkle of a clean acrylic bowl.

A motor tower wagon is essential for the maintenance of a large number of 25-ft. lanterns. The vehicle can be adapted to carry all necessary spares, cleaning materials and accessories.

For scouting, a 10-cwt. van fitted with a double extension aluminium ladder (13 ft. 9 in. when extended) is very useful. The interior of the van is fitted with shelves and lockers.

(7) Conclusion

The paper has outlined the steps taken by this local authority in planning the public lighting of a large district so that it can be commenced and carried through in stages as a unified scheme.

At December, 1953, some 1,305 lanterns were in commission. At some yet undefined date the completion of the task will see nearly 10,000 lanterns installed, and the district may well be justified in claiming a Public Lighting Installation second to none.

My thanks are due to Mr. J. H. Melville Richards, Engineer and Surveyor of the Harrow District Council, to the Eastern Electricity Board for permission to use the information given in this paper, and to the General Electric Company for assistance so readily provided.

Discussion

MR. C. C. SMITH: One of the first interesting points I came across was the excellent and commendable co-operation exhibited by the adjacent local authorities in this, shall I say, master plan of street-lighting improvement. I think the type of co-operation which was exhibited is typified by the sentence on the bottom of page 265, which says that after discussing the problems involved, standards of illumination were decided upon, but "The method used to obtain the minimum standards of illumination was left for the decision of each local authority." I think that is very important because it does leave individuality to express itself, which I feel in these days is very, very desirable.

Much has been said about uniformity of lighting, but I think we ought to be rather more explicit and state the difference between uniformity of type and uniformity

of standard. I rather feel that what we want is a uniformity of standard but very definitely not a uniformity of type. Standardisation can produce a very dull and uninteresting result and a little variety is all to the good provided the standard maintained is high. We all have different tastes and it is good to see some variety.

With regard to another item in the paper—trial installations—I was very interested to read about them. The author did not state whether the fluorescent lanterns used were vertical or horizontal, but probably the vertical lanterns were not in being at that time, and I assume that they were all horizontal types.

The case quoted of Manufacturer D. encourages me to speak again about enclosed and open lanterns. Mr. Durbridge mentioned the fact that one of the lanterns was found to be a dust trap. Now, our experience has been that, whilst the totally enclosed lantern may have many attributes, it does involve hinges, complicated catches and some form of leather, rubber or felt gasket, which quite often is seen hanging down from the lantern, not having been put back properly when the lantern was closed. This is no reflection on lantern design but rather an example of the understandable failings of human nature when men have to work sometimes in rather extreme conditions. The dust does get in, and renders cleaning much more difficult in the end.

On page 267 the author mentions the preference for concrete columns. I would like to ask him if there was any question of prestressed concrete or whether it was just ordinary reinforced concrete.

Towards the end of paragraph 3.2 he mentions the experiment carried out to convert an existing cast-iron standard and, also, when reading the paper, he said that it was almost as cheap to get a new one. In the paper itself he states that it is cheaper to provide a new concrete column. I would like to have a few figures for that, because a new concrete column is going to cost about £8 at least. I know that service-line charges are high, but do not think that that extra three yards of service cable up the column and the switch fuse box would cost that amount.

With regard to sodium lighting in shopping areas, which is mentioned on page 5 under the heading of "Final Policy," I think that the disadvantages of sodium lighting in shopping centres are very much over-emphasised. When all is said and done, you are not endeavouring to light shop windows—that is an individual job with a special technique—and when it is done properly the external lighting has very little effect upon it. If you are thinking about the people in the street itself, you will find that if shop window lighting is encouraged, the over-spill light from the window will provide all the colour correction needed on the pavements for those people who want to look beautiful.

You have heard the saying, "Manchester man, Liverpool gentleman." We are told in Liverpool that a man meets his wife in the drawing room, not in the shopping centre, and I fail to see why the ladies want to look particularly beautiful when they are shopping or when they are parading at night. An excellent and pleasing effect can be obtained by a centrally suspended sodium installation with reasonable shop-window lighting in a shopping centre.

There was another sentence to which I rather took exception, because I am so keen on sodium lighting, and that is at the bottom of page 267, where Mr. Durbridge says: "The Ministry also pointed out that fluorescent lighting would be approved only for the principal shopping areas of the district. This was a disappointment to the Local Authority who were planning a first-class lighting service for the district." The inference there is that by using sodium you cannot get a first-class lighting installation, and I would like here to heartily disagree.

On page 268 he mentions the fact that sodium lighting was used for side streets, but he goes on to mention malicious damage. I think that probably in certain areas it is more prevalent than others, but sodium lighting in side streets can be a very

expensive business indeed, and if there is an argument against sodium lighting, I would suggest that possibly that might be one in the case of side streets, and it would, of course, apply to all discharge sources.

On the same page, paragraph 4.1, under the heading "Installation Design," he mentions another point upon which I am reasonably keen, and that is cut-off lighting. One of the main arguments against it has been cost because of the rather closer spacing which is essential for a good job, but, as Mr. Durbridge points out, in very many cases these days, with our newer ideas of space/height ratios, spacings are down to, at the most, 120 ft., and quite often, as he says, 110 ft. He says: "In order to comply with the Ministry of Transport's recommendations for the lighting of bends, junctions and traffic roundabouts, there are many lanterns sited at between 80 and 90 ft. apart." If you are going to have spacings of that nature, you can get an excellent cut-off installation, far better than those excellent ones we saw on the screen, despite the fact that you cannot always judge by a photograph, because the photographer usually asks you which picture you want to look the best.

On page 269 he does mention one small point, that you get group control from a switch conveniently placed in a sub-station. Now, convenient to whom? Convenient to the Electricity Board—yes, but to the local authority—not necessarily. If the board are doing your maintenance, probably yes, but we have found in doing our own maintenance that a switch in a sub-station can be most inconvenient.

There is just one point I would like to mention on costs. I know definite figures can be misleading, but, taking the general figures he quotes, the cost for the maintenance of a fluorescent installation is £12 per lantern per annum, which includes energy, maintenance, lamp replacement and scouting, and for a 140-watt sodium installation he quotes £11 per lantern per annum, which shows a saving of £1 per lantern per annum. Now, we find that, for energy and lamp replacements only, the 140-watt sodium is 30s. less per annum than the fluorescent. This seems to indicate that sodium is 10s. per lamp more for the remaining maintenance, which I cannot believe. I would like him to say how this comes about.

I would like to say also that I personally feel that scouting or inspection every seven days is not sufficient. We in Liverpool deem it necessary—I think advisably so—to inspect every night. Again, he mentions cleaning four times per annum? I do not think that is sufficient, and that appears to be substantiated, because later on in his paper he mentions the embedded dirt and grime which require detergents of one description or another to remove. If fittings are cleaned frequently, then I think you will find that you will not need to use detergents.

He quotes capital costs: For fluorescent, £88; sodium, £68; and Group B sodium, £45. Could he say if service-line charges are included and, if so, what is the amount? It is a burning question on which we local authority lighting engineers are always very interested to have information.

On page 270 the author mentions a simple device for measuring the angle of tilt on sodium tubes. I would mention that there is a very simple and effective one available.

MR. J. M. WALDRAM: I would like to join in this discussion because I can say, from experience of living in and driving through the installations which Mr. Durbridge has described, that they are very good, an opinion shared by overseas visitors to whom I have had the pleasure of showing them.

I think it is fair to observe that it is not right to base a comparison of the old and new lighting on the relative merits of gas and sodium lamps. It is a comparison between a very old installation and a very modern one, each of them using the illuminant which was deemed to be adequate at the time: results as bad or as good

might have been achieved with other illuminants. Nevertheless, it is true that the old lighting was poor and in one instance very dangerous, in my view.

There are other new installations in the area which Mr. Durbridge does not show in his map—I think they must come under the heading of new works—so that the sodium lighting is rather more extensive than would appear from the map.

Mr. Durbridge deals with a problem rather different from the one we generally face in the I.E.S. The public lighting engineer has to light not a street but a district, and it is precisely the problem of lighting a district rather than lighting a street which I think is of interest. We should have liked even more information on the pros and cons of the various possible systems, and the reasons which led the authorities in Harrow to choose the method of lighting they did.

There is one feature of the question of individuality, mentioned by Mr. C. C. Smith, which is well illustrated in this area. The shopping centres have been lit with fluorescent installations so that as one goes through a long sodium installation, on coming to a fluorescent installation one says "Ah, here is a place." That is far more important than the appearance of people, or of goods in shop windows. I have not seen it better exemplified than along the Brussels-Antwerp road, where something similar has been done: after miles of cut-off sodium lighting, at each village they changed to the H.P.M.V. fluorescent lamp. Immediately the traveller knows that he has arrived somewhere, and it puts a pointer on his journey. I think that such variety is very important: if we light all our districts in exactly the same way, we shall be bored with them.

Mr. Durbridge mentioned that the planning was done by the local authority. Having seen the installations I have wondered whether they have stuck a little too closely to the book in some cases. I think they could have saved a few columns, and could have planned a little differently in some places, with advantage. For example, I have noticed one or two roads with shallow curves, particularly one where the lighting was at 15 ft. in a group B installation, where I think they kept too rigidly to siting on the outside of the bend, and have failed to give enough light to pedestrians on the inside of the bend. I think there are some lessons to be learned there. Where there are trees on the inside of the curve there are, of course, good reasons for siting only on the outside.

The installation of aero-screened lanterns was shown on a bend with lamps on the outside, where a conventional cut-off distribution would have succeeded. It would have been more interesting if Mr. Durbridge had shown us a staggered arrangement in the same installation, because it was particularly for that arrangement that the aero-screened distribution was worked out by the Ministry of Transport, after experiments had been carried out

Finally, there is the question of maintenance, on which Mr Smith's remarks were particularly interesting. I agree that an enclosed lantern must be and must remain properly enclosed : otherwise, all it does is to shut the dirt in, and you cannot easily get it out again.

The frequency of cleaning to which Mr Smith referred may just possibly be affected by local differences in the atmospheres at Harrow and Liverpool.

MR. F. H. PULVERMACHER: In South Wales there is an example of a main road which passes through several urban districts being lighted in a very uniform manner, due to the excellent collaboration between councils concerned. An extension of the scheme is now proposed and will be carried out as soon as the customary statutory consents have been received. When this new section is commissioned there will be a continuous length of about 20 miles of road having the same type of lighting, consisting of 140-watt sodium lamps sited in accordance with the latest planning practice.

However, Mr. Smith's plea for individualistic treatment has been met here inasmuch as the equipment varies in each district, the column and lanterns being of different makes.

In his paper Mr. Durbridge referred to the difficulty in getting sodium lamps correctly levelled. There is a very neat device sponsored by one of the leading suppliers of sodium lamps which consists of a plumb-bob operating against a "Perspex" scale. This merely hooks on to the lamp when adjustment is being made and it has been found that the device is both simple and accurate.

Mr. Durbridge makes mention of the fact that lamps which have been wilfully damaged become a charge to the lighting authority. I do not know whether Mr. Durbridge has experienced any difficulty in getting authorities to accept this view when the equipment remains in the ownership of the Area Board concerned, but in South Wales the view has been expressed by some of the lighting authorities that where lamps are maintained by a nationalised undertaking the latter should be responsible for all damage.

With regard to shorter mounting heights, it would be interesting to know if Mr. Durbridge has had any experience of acrylic refractor systems, particularly for lamps having a wattage centred on 100.

Concerning the fluorescent installation which the author has described, perhaps he would be good enough to inform this meeting whether quick-start or switch-start tubes are used.

Where lamps are sited near to railways difficulty, too, has been experienced in South Wales, and the trouble has been surmounted by using a lantern primarily designed for use in the proximity of airfields.

With regard to concrete columns, which have been, and still are, a very controversial subject, speaking personally I range myself against the iconoclasts since few of them can be considered as things of beauty. The fact that they enter into practically every scheme with which we have been concerned is due to the fact that there is no comparable alternative from the economic point of view, and I think tribute must be paid to designers for making the very best out of what I consider to be a sullen material. The fact that their use is now almost universal is because engineers have no real alternative, but I think that everyone will concede that they are bulky having regard to the duty they are called upon to perform, and it does seem that there should be some easier and cheaper way of putting a comparatively small lantern 25 ft. above road level than that of mounting it upon a sturdy and well-built concrete and metal structure.

A disadvantage of concrete columns which has made itself apparent in one or two places is that the top of the shaft cracks and even disintegrates, due to torsion caused by high winds acting upon the very considerable area of a fluorescent lamp fitting. It may be that Mr. Durbridge has not suffered from this trouble, but if he has perhaps he would inform us of the fact.

A reference to the frequency with which scouting should be carried out has already been made by Mr. Smith. Before going to South Wales I was accustomed to a system which called for scouting every night when lamps were alight. The advantage of such a system with regard to outages is apparent, but operating costs are undoubtedly high. On coming to South Wales I found, somewhat to my surprise, that a scouting frequency of once a week during normal working hours was generally accepted, and it does appear that this method presents no undue difficulties regarding the maintenance of a lighting system in efficient order. Naturally lamp failures do occur but these are accepted by the lighting authority and complaints are very few considering the large number of lamps concerned. It has been found that councils prefer to pay a lower charge, with the risk of occasional lamps being out for a few days, rather than pay a higher rate to cover a more frequent patrol.

It would be interesting to know what life Mr. Durbridge is getting from the

sodium and fluorescent lamps in the installations he is responsible for. In those with which I am concerned a recent check showed that with the four sizes of sodium lamps an average life of 3,600 hours was being obtained. It is interesting to note that the smaller sizes of sodium lamps have a considerably longer life than the large size, the range being from 3,000 hours for a 140-watt lamp to over 7,000 hours for a 60-watt.

It is always of interest to have information regarding the actual costs of erecting an installation, and I find that the figures given by Mr. Durbridge compare quite reasonably with those I have prepared for use at the present time. According to my reckoning a 45-watt sodium point is £38 10s., a 140-watt approximately £59, whilst a three-lamp fluorescent installation is in the neighbourhood of £95.

With regard to the service connections, concerning which there has been a certain amount of discussion during the course of this and other conferences, as far as can be ascertained the actual cost is in the region of £10 10s. This is for a lamp which is erected in the same footpath or verge as the distributing cable. Where a cross-road or lengthy surface is involved obviously the cost will be proportionately greater. This cost is included in the estimates I have just referred to. Perhaps Mr. Durbridge would be good enough to inform us how this estimate of mine compares with the costs incurred for service connections at Harrow.

Finally, I should like to put forward some figures showing the very great increase in the use of sodium and other types of discharge lamps that has taken place in South Wales Over the past two years the number of sodium lamps has increased from 1,500 to 3,700, or 246 per cent. of the original figure. In the same period the use of high pressure mercury vapour has entailed an additional 700 lamps, an increase of 130 per cent., whilst in the case of fluorescent lamps the increase is 200 per cent. This latter figure shows, however, how misguiding statistics can be when all the relevant factors are not given, since this increase of 200 per cent. is reduced to its true proportions when it is learned that even now there are only 320 such lamps in lighting compared with the very small number of 160 two years ago. It will be seen that the real increase is in the number of sodium lamps. It would be of interest if statistics covering the number and type of lamps in use for street lighting purposes throughout the country were made available.

MR. G. C. SMALL: On page 264 Mr. Durbridge refers to a minimum standard of 900 lumens for group B as a minimum. This appears to be rather low and I shall be interested to know what the standard is on the more important secondary roads.

Reference is made on page 266 to 2 x 80-watt fluorescent lanterns not being considered up to the desired standard. I suggest that the recent increase in the lumen output of lamps of this type should enable a minimum standard of 5,000 lumens to be achieved without serious difficulty.

On page 267 reference is made to fluorescent fittings with reflectors not being considered satisfactory. What grounds are there to support this view?

The placing of 60-watt sodium type lamps to indicate cross-roads would seem to be contrary to the final report of the M.O.T. I suggest that such a course would, in addition, be somewhat distracting unless one was resident in Harrow and was familiar with what had been done.

On the question of costs, I agree with Mr. Pulvermacher that the figures seem high and I shall be interested to know whether they include service connections and time switches.

I disagree with Mr. Smith on the question of scouting, because if the lamps are changed at regular intervals in accordance with their useful life—and this particularly applies to the discharge type—there is no need to inspect daily and probably twice or even once a week is all that is necessary.

MR. H. E. G. WATTS (written contribution): On page 269 Mr. Durbridge gives figures of relative capital and maintenance costs of fluorescent and sodium street lighting which show that the maintenance costs between the two do not vary very much, in fact approximately £1 per lantern per year. Now although the capital cost of fluorescent is about £20 higher, Mr. Durbridge does not mention whether he has considered the figures which would result from installing fluorescent throughout (which was the original wish of the Harrow Council) and using a fluorescent multi-lamp lantern, for instance a 3-lamp lantern, with all lamps operating to some convenient time such as midnight, and then extinguishing two lamps. My suggestion is that under these conditions it may well be found that the additional £20 per point capital expenditure would be offset by the reduced maintenance costs both for lamp replacements and current consumption, and in addition labour charges attached to these two items, and that it may well be found that a fluorescent installation with its many points of superiority over sodium would finally result, even over a loan repayment period, in a better financial proposition for the rate payers and in addition give them superior lighting.

Mr. Durbridge also mentions the use of ball joints for the levelling of sodium lanterns, but surely a far less expensive arrangement is to set the lantern level so that the appearance is acceptable and provide a very simple adjustment for the lamp within the lantern. The very small angular adjustment of the lamp which constitutes a relatively large light source in relation to the optical system is hardly likely to upset the light distribution to any measurable extent, and would, in my opinion, be a better proposition.

MR. DURBRIDGE (in reply): I would make it clear that with the fluorescent lighting installations only horizontal type lanterns were used. Mr. C. C. Smith's complaint that enclosed fittings are all dust traps can not now be justified since the introduction of one piece acrylic bowls. I agree that the lantern employing hinged sections of the acrylic material is to be avoided. With regard to the concrete columns, practically all are of the standard reinforced pattern. The experience gained so far with prestressed columns is not particularly favourable.

Mr. Smith's doubt as to the difference in costs in providing a new 15-ft. concrete column as against converting existing cast iron columns raises, of course, a controversial matter of long standing. The labour costs involved in adapting an existing column are very high and to this must be added the cost of the extra cabling for the service.

I believe in providing a form of illumination for public lighting that has the least number of disadvantages. Whilst it is generally agreed that sodium discharge lighting gives very good results, I think fluorescent lighting is better as there is no colour distortion, a point on which the public still holds very decided views.

In dealing with the control of the installation, it is now the practice to instal the timeswitch or relay in a box attached to the outside wall of the sub-station, where it is accessible to employees of the local authority and those of the electricity board.

In considering further the running charges for all-night burning for fluorescent and sodium lamps respectively, it must be remembered that the sodium lamp is the more expensive one to replace, whilst the energy charges for the fluorescent lighting are higher. In addition, the cost of cleaning a fluorescent lantern must obviously be more —the larger the lantern, the more to clean. The capital charges include the cost of the service lines. For a "normal" short service, say, within 12 ft., the charge is around £10 0s. 0d.; lengths in excess of this would be paid for on the actual cost basis.

Mr. Waldram is quite right in pointing out that it is not fair to compare gas with electricity in the examples shown on the screen. The installations chosen were merely taken to emphasise the urgent need that existed to bring the public lighting in Harrow to a level dictated by modern conditions. Though no doubt there is something in Mr. Waldram's arguments in favour of fluorescent lighting in shopping districts, there

is now a tendency to discount the distortion caused through sodium lighting. There is plenty of evidence that the shopkeeper, by correctly lighting his own windows, is not worried by the street lighting installation.

Mr. Pulvermacher's reference to a plumb-bob device for levelling sodium lamps shows that he, too, as well as Mr. Smith, has misunderstood the real problem; the problem is that although every care is taken to erect a column and fix the bracket and lantern to allow the cap of the sodium lamp to be about 2 deg. above the horizontal, there are numerous instances where the column is tilted away from the roadway, possibly due to the compression effect of the passing traffic. To alter the position of the lamp in the lantern to compensate for this is not satisfactory as the lamp would not then be in the correct position in relation to the optical system. What I am asking the manufacturers to do is to return to the practice of fitting a ball joint to the lantern itself to enable any subsequent errors to be corrected.

The work undertaken so far has, of necessity, been in the provision of 25-ft. mounting height columns and, therefore, the experience gained of acrylic refractor systems for the shorter columns is as yet limited. With regard to two other points raised by Mr. Pulvermacher, in six cases only is the quick-start pattern used for the fluorescent installation. Group replacement (or routine changing) of lamps allows 2,750 burning hours for sodium and 3,300 hours for fluorescent.

Mr. Small refers to the minimum standards of 900 lumens for group B roads as being too low. It must be pointed out that this was recommended and accepted some four years ago; no doubt when the time arrives for the Group B roads to be equipped note will be taken of any subsequent developments.

The choice of refractors in preference to reflectors was simply the result of a practical investigation. It was decided that the lantern employing reflectors needed far too much cleaning and maintenance whereas the sealed refractor is a very simple device to keep clean.

Mr. Watts's suggestion that it might have been worth while to instal fluorescent lanterns throughout by making use of selective switching was considered. It was not accepted for two reasons—firstly, the capital cost would still have proved a stumbling block and, secondly, it was not thought desirable to reduce the standard of lighting in any road even if the volume of traffic was very much reduced.

The Economics of Four Industrial Lighting Installations

The type of lighting adopted for any particular industrial building usually depends on a number of factors, including capital and operating costs, technical requirements and maintenance facilities.

Some of the problems involved are discussed in the four papers of this symposium. The papers were selected to illustrate the advantages of different lamps for particular applications. Although the papers have a common theme the treatment is individual.

(I) A Hot Cathode Fluorescent Installation

By S. T. CLARK

(1) Introduction

Up to the last war, woollen textile plants were very backward in lighting, amongst other things, but during the war years and the post-war period great strides have been made. Some firms formerly depended only on gas for lighting and many generated their own electricity, with no means of auxiliary lighting when the power plant was stationary. The mechanisation of the industry, so popular to-day, has done much to alter these conditions, and one can assume that a great number of woollen textile mills are now lit with mains electricity. This is generally a post-war development and hot cathode tubular fluorescent lamps have been chosen for lighting many mills, including the one described in this paper.

(2) Processes

The processes which take place in a woollen mill are described below. These are different from and more comprehensive than either the worsted or cotton processes, for they usually include the whole conversion from raw materials to woollen cloth.

(2.1) Raw Materials

The ingredients of a woollen cloth may include old rags, new rags, wool waste, virgin wool, cotton and the man-made fibres.

The rag department takes the rags or wool waste and " grinds " or pulls the cloth into fibre. In the blending or willeying departments all the ingredients needed for a particular blend are accurately weighed and mixed together to make a cloth of a certain quality, colour, texture or strength; vegetable oils (oleine) are added to help subsequent processing. After blending, these fibres are passed to the scribbling and carding department, where the fibres are combed and finally wound on to a condenser bobbin as a soft thread (Fig. 1).

(2.2) Thread or Yarn

The spinning process, either by mule or ring frame, spins the soft thread into a twisted yarn, suitable either as warp or weft, for weaving purposes (Figs. 2 and 3). The warp threads are wound on to cones and subsequently wound by means of the warping mill on to a warp beam ready for the loom (Fig. 4). The cloth leaves the loom ready for the further processing.

(2.3) Cloth

Burling and mending are the processes of inspection and removal of weaving faults. After burling the cloth is scoured to remove mill grease, milled, or felted, washed and tentered, or dried. Dyed cloths pass to the dyehouse for processing before tentering. The dried or tentered cloth is finished, being cut, or cropped, pressed, examined and delivered for packing.

Mr. Clark is with Henry Lister and Sons, Ltd. The manuscript of this paper was first received on January 21, 1954, and in revised form on March 11, 1954. The paper was presented at the Society's Summer Meeting, Southport, on May 20, 1954.

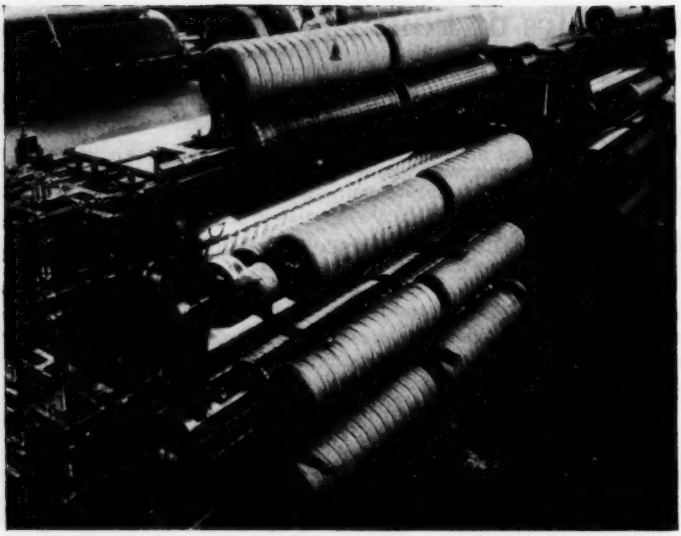


Fig. 1. Condenser end of woollen card.

(3) Requirements

In such a mill it is possible to break down the lighting requirements into three broad groups, although special consideration will be needed for lighting in some locations.

(3.1) Group A

The first group includes processes involving rag blending, scribbling and carding, spinning, winding, wet finishing, dyeing and the warehouse.

In almost all of these departments the operative's task covers a fairly large working area. For example a pair of spinning mules may take up an area of 2,200 sq. ft. and the spinner is watching threads over a distance of 90 ft.; a scribbling minder looks after two machines occupying an area of 2,000 sq. ft., the machines being 80 ft. long.

In all these areas a good general light is adequate for the visual tasks involved; the recommendation of the Wool Textile Industry Joint Advisory Committee states "A good system of general lighting should always be provided, thus reducing to a minimum the trying effects of variation in brightness over the working area. Local lights may be necessary to supplement the general lighting at particular points, as at the condenser end of a woollen card"[1]. The illumination varies between 10-14 lm./ft.^{2} in the scribbling department, and between 10-20 lm./ft.^{2} in the spinning department.

(3.2) Group B

This group includes the process of warping, weaving and finishing. These three departments may be compared with an engineering machine shop, a clothing factory, or the printing industry.

Warping is a process where, in a series of sections of about 300 threads, a warp of 2,000-3,000 ends is wound on to a "mill" or "balloon." Each thread is important and, when there are different colours, its position in relation to the whole is most important. To enable the operative to watch these threads carefully an illumination

of 25-30 lm./ft.^{2} is advisable. Weaving is similarly important. No thread must remain broken. This will be dealt with in greater detail later.

In the finishing processes, while a general shed illumination is necessary, the individual machines need local lights and an illumination of 25 lm./ft.^{2} is advisable.

(3.3) Group C

Included in this group are the processes of burling, mending and perching, and inspection, each of which requires a high level of illumination. Burling is done when the piece is taken off the loom; it is weighed, measured and then examined for weaving faults, thick pieces of thread, warp and weft threads missing, particles of foreign matter, etc. In a woollen cloth these faults can usually be rectified in this department.

In woollen flannels the cloth does not require the same accurate treatment for faults as in the worsted trade, where the mending process is of the highest importance. The process in both trades is the same, new threads being inserted where necessary.

For both of these processes 40 lm./ft.^{2} is considered to be a good level of illumination.

Perching and inspection is the "brightest" department of the factory, and requires exceptionally good lighting. The cloth is inspected several times during its final stages of finishing to make sure that no fault passes unseen.

Illumination levels for perching may vary from 40-80 lm./ft.^{2}, and it is most important that the illumination does not vary across the face of the cloth.

(4) Choice of Light Source

The choice of light source is partly decided by the construction of the factory buildings. The height of most rooms in textile factories is low in comparison to other industries. Those in multi-storied buildings are usually not more than 13 ft. high—indeed, many of the older ones are only between 10 and 11 ft. high—whilst North light sheds are generally only about 12 or 13 ft. to the gutter. This rules out immediately the blended light-and-discharge-lamp-type of installation, as both require a high mounting position.

The choice then rests between tungsten, hot-cathode fluorescent, and cold-cathode

Fig. 2. Mule spinning.

Fig. 3. Ring spinning.

fluorescent lamps. Rightly or wrongly, the industry is more and more replacing tungsten with hot-cathode installations. One of the reasons for this is the advantage of a 5-ft. source of light across the pieces of cloth, which usually are 4 ft. 6 in. wide. Cold-cathode lighting, with its high initial cost, greater bulk of equipment and high voltage operation, has not been generally considered. The final choice therefore lies between tungsten and hot-cathode fluorescent lamp installations.

At first sight, a fluorescent lamp consuming 90 watts appears to be better than a tungsten lamp consuming 150 watts, as its light output per watt is greater and the light distribution from the long linear source is better. There are, however, other factors, which vary with the level of illumination required, to be taken into account.

As stated in Section (3), lighting requirements fall into three groups, which can now be discussed in detail.

(4.1) Group A

For the purposes of simplicity the mule spinning section may be examined as typical of this group. No local lighting is necessary, but a good overall general illumination is important. Particular care has to be taken to ensure good lighting at a point 2 ft. in front of the rollers when the mule is closed.

Originally this area of the mill, which is 92 ft. by 168 ft. and in which 14 mules are installed, was lighted by 14 rows each of eight fittings; there was very little optical control. Readings taken in 1938 showed illuminations of 10 lm./ft.^{2} under the fittings, 2 lm./ft.^{2} between mules and 4 lm./ft.^{2} between fittings. This was most unsatisfactory, but was accepted because the shed lit by 112 x 150-w. lamps, almost unshaded, gave an impression of brightness which was very deceiving. This installation was replaced with one of 154 x 150-w. lamps, using direct reflectors. While the illumination values vertically beneath the light sources were high (25 lm./ft.^{2}), those between the sources were not very good (8 lm./ft.^{2}), whilst between the pair of mules the illumination only just complied with the minimum requirements of 6 lm./ft.^{2}.

The present installation, consisting of 14 rows each of nine single 5-ft. 80-watt fluorescent lamp fittings, gives an illumination of 18-20 lm./ft.^{2} down the line at 2 ft. from the rollers, and a minimum of 10 lm./ft.^{2} in the centre between the pair of mules (Fig. 2).

Table 1

Comparison of Tungsten and Fluorescent Lighting Installations on Mule Spinning Section (Based on 3,750 hours' use per annum).

	Tungsten	Fluorescent
Lamp wattage	150	90 (incl. losses)
Number of fittings	154	126
Number of Units of Electricity	86,625	42,525
Cost at 1.1d. per unit	£397	£195
Lamps replaced during year	$\frac{3{,}750 \times 154}{1{,}000} = 578$	$\frac{3{,}750 \times 126}{5{,}000} = 95$
Cost of lamp replacements	£78	£68
Cleaning at 3/6d. hour	nil	$126 \times 3/6d.$ £22
Maintenance at 4/- hour	nil	£7
Total cost	£475	£292

(4.1.1) *Comparison of Tungsten and Fluorescent Lighting*

As the original scheme did not conform to the requirements of the Factory Act, only the intermediate and final schemes will be considered for comparison purposes.

The Department works 24 hours a day for five days a week, so assuming that in the summer months the installation is in use for 10 hours a day and during the winter for 20 hours a day, the total operating period per annum is 3,750 hours.

The life of tungsten lamps is generally taken as 1,000 hours, and this figure is used in the paper even though it may vary in practice according to local conditions. Similarly the generally accepted figure of 5,000 hours for the life of fluorescent lamps is used. With the tungsten lamp installation no cleaning was carried out, and the level of illumination therefore gradually deteriorated. The fluorescent fittings are washed twice a year. For the tungsten installation there was no apparent maintenance charge as the spinner changed his own lamps; the fluorescent lamps are changed by the electrical staff, the time taken being on an average about 20 minutes per lamp.

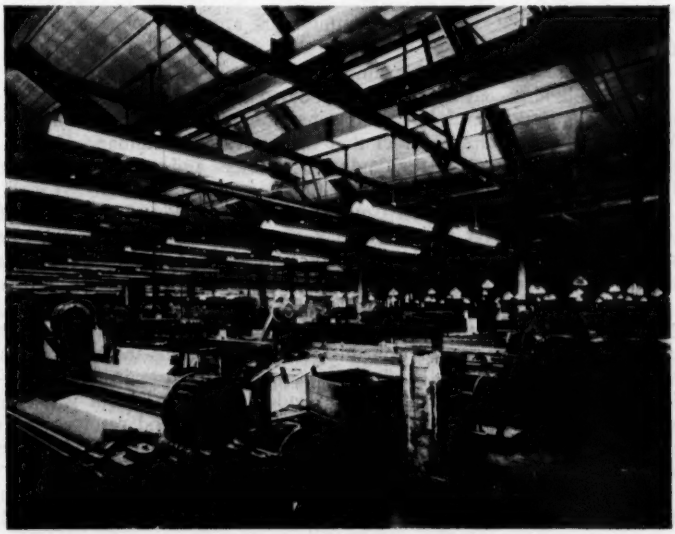


Fig. 4. Weaving shed.

(4.1.2) *Running Costs*

The comparison of running costs of the two installations is given in Table I. The balance of £183 in favour of the fluorescent installation is not all profit as the capital outlay in terms of depreciation is still to be taken into account. The new installation, however, gives more light than the previous one and is better than that required under the Factory Act. Satisfactory results could also have been obtained by using only eight fittings per mule when the "credit balance" would have been increased by another £30.

(4.1.3) *Capital Costs*

As it is necessary to light a factory in order to work therein, there is a certain cost which cannot itself be expected to justify the lighting installation. That is a normal overhead charge which is reflected in the price of the commodity which is manufactured. The cost of tungsten fittings (being the lowest initial expense), together with all the conduit, cable, switches, fuse boxes and wage costs, can be taken as a necessity, and the only charge that needs to be taken into account in comparing the two types of installations is the difference in cost between the fluorescent and tungsten fittings.

The cost of 154 x 150-w. tungsten R.L.M. reflectors, complete with lamp-holders and lamps, is £123. The cost of 126 industrial type fluorescent fittings, complete with lamps is, say, £1,260. The difference of £1,137 can be assumed to be an addition to capital, which must be reflected in the saving in running costs.

It is understood that 9 per cent. is a reasonable figure for annual depreciation, and 15 years a fair life of a fluorescent fitting. A 9 per cent. diminution depreciation on £1,137 for 15 years is equal to an average of 5 per cent. on £1,137; 15 years' depreciation at this rate is £855, or £57 per year. To arrive at a total depreciation over 15 years, the difference of £282 must be added and the £57 per annum is increased by £19 (£282 ÷ 15) to £76 per annum.

These figures are very satisfactory from an economic point of view. Couple this with the better illumination which is enjoyed, and the reason why tungsten lighting is being replaced by hot cathode fluorescent lighting for general requirements is easily understood.

(4.2) Group B

In this section the best example is the Weaving Department.

It is obvious that if the usual poor tungsten lighting is replaced by a good hot cathode fluorescent installation the previous group figures will not be applicable. We must either accept the fact that the increased illumination has a value which is justified by factors other than pounds, shillings and pence, or else compare a good fluorescent installation with a good tungsten one.

In the Medical Research Council Report No. 81, "The Effects of Conditions of Artificial Lighting on the Performance of Worsted Weavers," Weston says in the conclusions, "In general, it appears that an average illumination of about 30 lm./ft.^{2} on the cloth is necessary for high efficiency in weaving fairly dark cloth."(2)

This Report was published in 1938 and so was concerned only with tungsten lighting. Nine different experiments were tried, using reflectors varying from the deep conical enamelled steel type to focusing mirror type. It seems the best results were achieved with Standard Dispersive Reflectors using, in the first instance, 150-w. lamps and, in the second, 200-w. lamps. Four hundred watts per loom was considered to give good results and 500 watts per loom to give very good results. With the 400 watts per loom experiment the illumination was 40 lm./ft.^{2} on the cloth and 15 lm./ft.^{2} on the shuttle box.

Fluorescent lighting permits some improvement. Two 80-w. lamps set at right angles to the loom give a more balanced illumination, slightly lower in value on the

Table 2

Comparison of Tungsten and Fluorescent Installations in Weaving Shed with 100 looms (Based on 3,750 hours' use per annum).

	Tungsten	Fluorescent
Lamp wattage	400	180
Number of units of Electricity	150,000	67,500
Cost at 1.1d. per unit	£688	£309
Lamp replacements during year	$\frac{3,750 \times 270^*}{1,000} = 1,018$	$\frac{3,750 \times 200}{5,000} = 150$
Cost of lamp replacements	£138	£102
Cleaning	nil	£35
Maintenance	nil	£12
Total cost	£826	£458

* Weston used both 150- and 200-watt lamps in his experiments. For ease of comparison the number of tungsten lamps in use is taken as 270, i.e., total wattage of tungsten lamps /150.

cloth but higher on the shuttle boxes and better at the healds and the reed or "going" part. Thus we can compare 400 watts of tungsten with two hot cathode lamps at, say, 180 watts.

From this we can use the same calculation as in Group A and on the basis of 100 looms working night and day with the same hours of lighting the figures given in Table 2 are obtained. These show a cost advantage in favour of fluorescent lighting of £368 per annum.

Using the same depreciation figure as before, 200 fittings at £10 capital cost will be completely covered on a 15-year life by a figure of £133 per annum.

The superstructure of the loom constitutes an obstruction problem which cannot easily be overcome with tungsten lighting, but a 5-ft. fluorescent lamp set across the loom almost completely overcomes the difficulty. It is important that the fitting be at right angles to the path of the shuttle. As the overall width of the loom is 13 ft., two such lamps set 5 ft. apart are more than sufficient to provide first-class lighting.

(4.3) Group C

The justification of a high illumination for the processes of this group must not be calculated in direct monetary value. Inspection at all times requires good seeing conditions.

Burling perches and mending tables were previously lighted by single 150-watt lamps; they have now been replaced by single 80-watt fluorescent lamps. The comparison is therefore between 150 watts of tungsten and 90 watts of fluorescent with a much better illumination with the latter source across the full width of the cloth.

Mending perches have side lighting in addition to that from the one overhead 5-ft. lamp; the finishing perches have an overhead fitting containing four 5-ft. lamps which gives much improved results. One important problem was the final passing which could only be carried out in daylight as the tungsten lighting was not considered satisfactory. Even 5-ft. wide fluorescent fittings were not suitable as there was a drop in illumination towards the edge of the cloth. By using two fittings each containing four 4-ft. lamps side by side, the final passing can now be carried out at all times of day or night.

As these special lighting points are few in number in relation to the total lighting of the factory, any apparent extravagance in the way of excess illumination is not a serious matter. On the contrary, the better conditions of lighting at this stage in the process of cloth manufacture more than justify the installation.

(5) Conclusions

It can be said that if a good system of lighting is required hot cathode fluorescent lighting is cheaper than tungsten lighting for the woollen industry, and no other factor is necessary to convince the woollen manufacturer of the value of such an installation.

As so much is said, and written, about the value of good lighting as an aid to increased production, better standards of workmanship and an inducement to operatives, this paper would not be complete without some expression of opinion based on practical experience.

It is reasonable to assume that a new and better lighting installation will give some increase in production, especially if the old installation was not satisfactory. Obviously, if the old system is so poor that it actually retards production, then increasing the illumination will remove the "brake."

The improvement of illumination alone, say, from 8 to 20 lm./ft.^{2}, or from 20 to 40 lm./ft.^{2}, does not necessarily bring about improved production. There is not the slightest doubt that, while tests are being taken and interest shown, the operative will be spurred to increased output. Usually, when figures are prepared, the immediate improvement is shown. It would be interesting, however, to see figures taken, say, two years after the new lighting system was installed. It is possible that if allowance is made for other factors, no appreciable increase in production will be noticed.

Weston showed[2] in a table of relative output of day weavers, an increased average output of only 1.6 per cent. on 48 weeks with an output varying from 96.0 to 106.9 against the original figure of 100. His night weaving record showed on the same basis a 4.9 per cent. increase with an output varying from 101.1 to 108.0 against 100. Of course, the original lighting was not very good.

Table 3
Recommended Values of Illumination for a Woollen Mill

	lm./ft.^{2}
Rag grinding	6-8
Blending	6-8
Scribbling or carding	10
Spinning, mule and frame	15
Winding	15
Warping	25
Weaving	30
Burling and mending	40
Wet finishing (scouring, milling, washing)	8
Finishing (machine)	25
Finishing (inspection)	80

Better lighting provides the opportunity for better quality workmanship, but it does not follow that the opportunity will be taken. That, however, is not the fault of the illuminating engineer; it is a matter of labour control. Improved lighting conditions should improve standards of workmanship. It is questionable whether all the improvements and amenities which could be carried out by a factory management do, in themselves, constitute an inducement to labour during a time of full employment. However, it is generally accepted that good lighting is one factor in the establishment of friendly relations between employer and employee, and as such has a value which cannot be readily assessed.

References

(1) Final report of the Wool Textile Industry Joint Factory Advisory Committee (1949).
(2) Medical Research Council, Industrial Health Research Board, Report 7,681, "The Effects of Conditions of Artificial Lighting on the Performance of Worsted Weaving," H. C. Weston (1938).

(2) A Cold Cathode Fluorescent Installation

By W. HOWE, A.M.I.E.E.

(1) Introduction

This paper describes the lighting installation of a large engineering factory where high quality precision work is carried out. The employment of shift workers means that artificial lighting is in almost continuous use.

The combined lighting and power requirements of the plant entail very heavy consumption of electricity, whilst the repetitive nature of the work ensures that maximum demands can be monitored and the load factor maintained at a high level.

The combination of these circumstances results in an advantageous tariff, an important factor in deciding the type of lighting.

(2) Nature of Premises

The premises consist of a number of large factory bays of north light roof construction, the height to the eaves being 17 ft. This height must be left free of all obstruction to permit the passage of mobile cranes and to ensure that maximum height is available for high machines which may, under certain organisational programmes, be placed at any spot within the working area.

The factory is sited in a rural area where the air is reasonably clean and free from contamination. The work itself does not give rise to corrosive or dirt laden fumes.

(3) Lighting Requirements

A minimum illumination of 25 to 30 lm./ft^2 was considered necessary over the whole factory area. Although this might be higher than the illumination required in a minority of departments, the factory and its services were designed for flexible organisation of production. It was visualised that the general character of the products would be unchanged but that progress in design would compel periodic redeployment of plant and the introduction of additional machines.

Since the work would call for great accuracy, a high level of illumination was required on the actual working points, with a minimum of shadow. This effect was desired without recourse to local lighting, except for the illumination of internal borings which obviously could not be lighted from external sources. The optimum efficiency was required from the lighting installation. Therefore, the use of diffusing screens to prevent glare from light sources was deprecated.

The factory would be working night and day; hence continuity of production would depend upon continuity of lighting. A light source as free from failure as possible was therefore needed. Further, at a time when fluctuations of voltage were liable to occur, lamps were required which would be least affected by such changes.

The colour consideration was important and a "natural" effect was desired.

(4) Choice of Light Source

Light sources with strong colour characteristics, such as high pressure mercury vapour and sodium vapour lamps were eliminated as they were unsuitable for the working conditions required.

The choice of source thus lay between :—

(i) Tungsten.
(ii) Blended tungsten-mercury.
(iii) Hot cathode fluorescent.
(iv) Cold cathode fluorescent.

Mr. Howe is with Donald Smith, Seymour and Rooley, Consulting Engineers. The manuscript of this paper was first received on January 4, 1954, and in revised form on March 10, 1954. The paper was presented at the Society's Summer Meeting, Southport, on May 20, 1954.

(4.1) Tungsten and Blended Tungsten-Mercury Lighting

Tungsten and blended fittings have a rather high surface brightness due to the large light output from a small source. In this factory, the height at which the fittings had to be mounted and the large expanse of the workshops meant that the light source would inevitably be visible to the operatives. To employees engaged on precision work the contrasts provided by tungsten and blended fittings were highly undesirable.

Moreover, the tungsten lamp's short life of 1,000 burning hours would mean frequent maintenance and even if group replacement of lamps were adopted the possibility of some failures could not be ignored.

It has frequently been demonstrated that the total costs of tungsten lighting are not significantly lower than more modern forms of illumination and when lamps are in use many hours each day the cost of tungsten installations is usually the higher.

For these reasons, the above lamps were not selected.

(4.2) Hot Cathode Fluorescent Lighting

Hot cathode fluorescent lighting obviously had to be considered, and met many of the specified requirements. Surface brightness of the lamp is low, so reducing glare; the lumen output per watt is good and the life expectancy of the lamp is comparatively high.

At the time when this installation was being designed the "instant-start" fluorescent lamp was in a very early stage of development and there was a tendency to judge hot cathode systems on the experience of switch-started units. Subsequent development of the instant-start gear does not greatly influence the economics of the calculations shown later, as the saving on switches is to some degree balanced by the increased cost of the gear and lamps.

The spacing-height ratio and the required high level of illumination led to the consideration of twin-lamp 80-watt units, mounted in a metal reflector designed to give a small amount of upward light. The modern claim of a life of 5,000 burning hours was not at this time being made by all manufacturers. Investigations tended to show that this figure should be regarded as an absolute maximum; recent observations show that this assumption was not unreasonable, and the lesser figure shown in the calculations is considered a fair average.

(4.3) Cold Cathode Fluorescent Lighting

The final source to be considered was the cold cathode fluorescent lamp.

Cold cathode lighting is, of course, widely used for decorative and architectural illumination where tubes can be individually shaped to suit particular features. In industry, the self-contained lighting unit embodying the necessary transformers and capacitors is the relevant arrangement.

Cold cathode lamps have many properties which are particularly suitable for the requirements described. They have an exceptionally long life—of the order of 15,000 burning hours. This is a notable advantage when loss of production is considered, in addition to the considerable saving in the cost of lamp replacement. The low surface brightness, around 2.8 cd./in.^{2}, and the wide spread of light from the fittings are other features which add to their merits. They share with hot cathode lamps the advantage of a low fall in light output when the supply voltage is lowered. The percentage lumen output is almost exactly proportional to the applied percentage of the nominal voltage. This is similar to the characteristics of the hot cathode lamp but better than that of the mercury vapour lamp and very much better than that of the tungsten lamp. There is almost no flicker from the units, and the stroboscopic effect is reduced to a minimum. In machine shops with large numbers of rotating shafts and gears this is a safety factor of great importance. The lamps will start and will continue to burn at voltages well below the foreseeable mains variations.

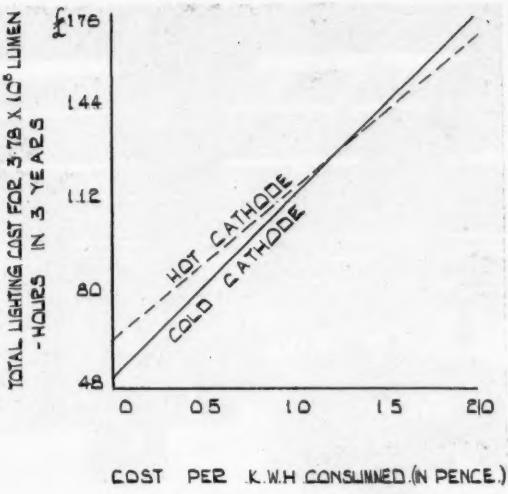


Fig. 1. Showing variations in total lighting costs with variation in cost of electricity.

A wide range of colours is available, and a "natural" colour was selected as being suitable for the desired effect.

The above features made the cold cathode lamp the most suitable source for this particular installation. Examination of the available types of unit led to the choice of a four-lamp 10-ft. fitting with a light output of 10,000 lumens and a consumption of 390 watts.

In this fitting the lamps are wired in pairs, each pair forming a series circuit. Thus if one lamp develops a fault only half of the fitting is out of action.

The choice of any lighting system must always depend on two factors—suitability and cost. To justify the use of a particular system, when a degree of suitability is satisfied, it is only necessary to show that the selected system achieves parity, or even near parity, of costs with a comparably suitable alternative. Prevailing circumstances will always affect comparisons, but it will be seen that for the conditions applying to this installation cold cathode fittings were rather more economical than the alternative hot cathode fluorescent lighting.

(5) Economics of Cold Cathode Lighting

The comparison in costs between different lighting systems necessarily involves certain assumptions and can become complicated and possibly fallacious if one attempts to devise a formula which is universally applicable to all types and conditions of lighting, burning hours and tariffs.

The present comparison is, therefore, restricted to the two light sources which were chosen on the grounds of suitability, i.e., hot cathode and cold cathode fluorescent lighting.

The figures shown are not intended to meet the maximum claims made by the manufacturers of either type of fitting. They are conservative estimates which, in the author's experience, can be shown to be attainable in practice, under the type of conditions prevailing at the factory in question.

It is felt that computations should be made in a practical manner and that close approximations are justified, to clarify working and to demonstrate easily comparative

Fig. 2. General view of installation.

costs of the various items comprising the total lighting expenses. Where approximations are used care has been taken to ensure that they balance for each fitting and do not give rise to a cumulative error.

The fittings selected for comparison are the twin-lamp 80-watt hot cathode fluorescent unit and the four-lamp 10-ft. cold cathode unit, both having white enamelled trough reflectors giving some upward light. The prices chosen for the fittings are standard trade prices normally available to large buyers, to which have been added sums to cover average installation costs in this type of factory.

The cost of power consumed is the average price per unit and includes all factors comprising the total charge. It is considered unnecessary to show separately the effect of maximum demand and unit charges as the ratio of load to units consumed is constant and, on a load which is virtually in continuous use, can be satisfactorily embodied in the average price per unit.

Twin-lamp 80-*watt hot cathode fitting with "natural" lamps, gross light output* 6,000 *lumens*:

Consumption, including gear losses	200 watts.
Life expectation of lamps	4,200 burning hours.
Life expectation of starting switches	6,300 burning hours.
Cost of a fitting and installation	£16.
Cost of lamp replacement, including labour	£1
Cost of switch replacement, including labour	10s.

Four-lamp 10-*ft. cold cathode fitting with "natural" lamps, gross light output* 10,000 *lumens*:

Consumption, including gear losses	400 watts.
Life expectation of lamps	14,000 burning hours.
Cost of a fitting and installation	£33.3
Cost of lamp replacement, including labour	£2.

Operating Conditions:

Average cost of one k.W.H. of electricity .....1d.
Burning period .....12,600 hours in three years.

To simplify comparison between the two systems, the cost of operating (a) five twin-lamp 80-watt hot cathode fittings and (b) three four-lamp 10-ft. cold cathode fittings has been calculated for the stated burning period, as the light outputs from these two groups of fittings both equal 30,000 lumens.

Calculation A—Hot Cathode:

$$\text{Cost of power} = \frac{£5 \times 200\text{W.} \times 1\text{d.} \times 12{,}600 \text{ hours}}{1{,}000 \times 240} = £52.5$$

$$\text{Cost of lamp replacement} = \frac{£1 \times 10 \times 12{,}600}{4{,}200} = £30.0$$

$$\text{Cost of starter switch replacement} = \frac{£.5 \times 10 \times 12{,}600}{6{,}300} = £10.0$$

Interest and depreciation for 3 years at 10 per cent. p.a.

$$= \frac{£5 \times 16 \times 3}{10} = £24.0$$

Total cost for three years = £116.5

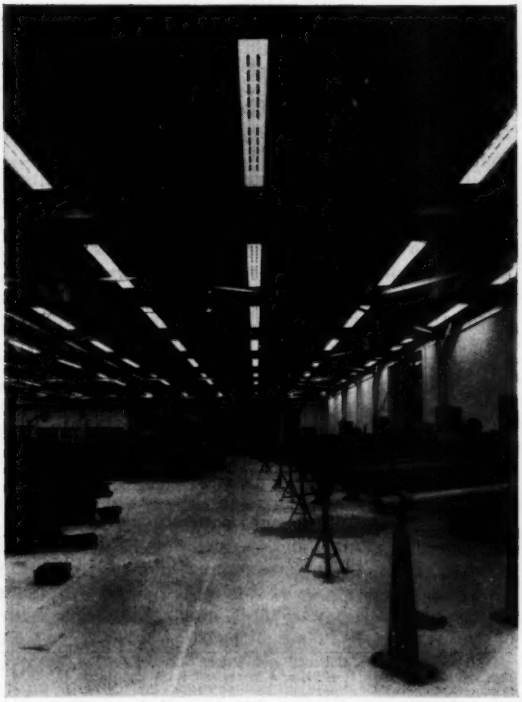


Fig. 3. General view of installation.

Calculation B—Cold Cathode:

$$\text{Cost of power} = \frac{£3 \times 400W \times 1d. \times 12{,}600}{1{,}000 \times 240} = £63.0$$

$$\text{Cost of lamp replacement} = \frac{£2 \times 12 \times 12{,}600}{14{,}000} = £21.6$$

Interest and depreciation for 3 years at 10 per cent. p.a.

$$= \frac{£3 \times 33.3 \times 3}{10} = £30.0$$

Total cost for three years = £114.6

N.B.—Chokes, transformers, etc., have been regarded as non-expendable and their maintenance is covered by depreciation figures.

(6) Conclusions

It will be seen that for the given conditions the cold cathode system is more economical. Whilst the calculations are based on a particular combination of circumstances, it is simple to substitute figures which would apply under different conditions. As an example, the graph of Fig. 1 shows the alterations in costs when the price of power is varied, and demonstrates the marked difference in economics when a single factor is changed.

Major sections of the installation have now been in use for some 18 months. The desired effects have been obtained; the illumination is uniform and adequate. The general appearance of the factory is light and congenial; no discomfort is experienced from glare. General views of the installation are shown in Figs. 2 and 3.

In a section using 600 four-lamp fittings, after nearly 10,000 burning hours, only three single lamps have been replaced as faulty. There have been no failures of transformers or other components. A total of nearly 2,600 four-lamp fittings were used throughout the whole installation.

Cold cathode lighting provides a valuable addition to the resources of the illuminating engineer, and the claims made for it are doubtless justified.

It should be emphasised that there is no intention to recommend this form of lighting for all or any general circumstances. The conditions and economics of every installation must be considered as a separate problem. This paper has dealt with one set of lighting requirements and costs, and has attempted to illustrate in a practical manner the process behind the design of a lighting project.

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(3) A High Bay Mercury Lighting Installation

By F. JONES

(1) Introduction

It was decided to replace the existing lighting in the crane shop of a large engineering works and this paper, after discussing the various problems involved, analyses the installation and operating costs of three lighting schemes. On the basis of this analysis 1,000-watt mercury vapour lamps were chosen for the installation.

This crane shop is a structural steelwork building with roof trusses spaced every 12 ft. 6 in. The bay is 400 ft. long x 62 ft. wide, with a height from floor to underside of roof truss of 50 ft.

Mr. Jones is with Babcock and Wilcox, Ltd., Renfrew, Scotland. The manuscript of this paper was first received on February 1, 1954, and in revised form on March 15, 1954. The paper was presented at the Society's Summer Meeting, Southport, on May 20, 1954.

(2) Types of Lighting

Four factors had to be considered when deciding the type of lighting to be used :—

(i) An average illumination of 15 to 17 lm./ft.^{2} was required for the bay, in which marking out and detailed construction work are carried on. Good distribution of lighting was required, as many large and tall crane structures are erected in this shop.

(ii) It was desirable that the number of fittings should be as small as possible to minimise the inevitable interruption to production while the fittings were being installed.

(iii) To facilitate erection and wiring it would be necessary to use the overhead travelling cranes which would only be available for limited periods during the day and at week-ends.

(iv) The shop is on day and night shifts so again the smaller the number of fittings the less the interruption caused when cleaning and maintaining the units.

While satisfying these conditions, it was necessary to choose the most economic lighting system. To make the necessary comparison between different systems, the number of fittings required was calculated for an average illumination of 15/17 lm./ft.^{2}. Three types of fittings were considered for this installation, namely 1,000-watt mercury vapour, 400-watt mercury vapour and 1,000-watt tungsten.

(3) Comparison of Lighting Systems

(*i*) 1,000-*watt* 440-*volt Mercury Vapour Discharge Lighting.*

Units of this type have the advantage that both lamp and fitting are specially designed for high bay mounting. The mounting height maximum/spacing ratio for these units is 1 : 1, but for this particular installation the spacing had to be less than the maximum to obtain the illumination required.

Thirty-one fittings were required to give the specified illumination of 17 lm./ft.^{2}, and as 31 trusses were available for their support, a staggered formation of one lamp per truss was possible. This formation minimises loss of light during transition of overhead travelling cranes.

(*ii*) 400-*watt* 250-*volt Mercury Vapour Discharge Lighting.*

To give the necessary illumination, approximately 105 fittings of this type were required, but if a desirable symmetrical layout was to be achieved, only 93 could be accommodated (3 per truss).

(*iii*) 1,000-*watt* 250-*volt Tungsten Filament Lighting.*

The calculated number of fittings required for an illumination similar to the 1,000-watt M.V.D. scheme was 85, but again demands of symmetry meant that this number would have to be reduced to 78 (three and two fittings per truss alternately).

The illumination values which would be obtained with the three systems using the stated number of lamps were 17 lm./ft.^{2}, 15 lm./ft.^{2} and 15.6 lm./ft.^{2} respectively.

When comparing the three types of lighting, a factor which had to be considered was whether the building could readily accommodate any particular scheme without major structural alterations; if not, the installation costs would be excessive. For example, if, by calculation, 105 400-watt mercury fittings are required to give 17 lm./ft.^{2} and only 93 can be accommodated on the trusses, then the lower illumination would have to be accepted, as the alternative of fitting special structural steel work between the shop trusses to support an unbalanced lighting layout was not acceptable. This is a practical aspect which is often overlooked.

For the purpose of the economic survey, the actual installation of equipment for

each lighting system was considered, as far as is possible, as having similar salient features, namely:—

(i) 4-in. x 4-in. steel trunking would run longitudinally in the bay, spanning the roof trusses.

(ii) Lighting would be switched in groups from a central control switchboard; each group would be controlled by a 30-amp T.P. switchfuse.

(iii) Each lighting fitting would be suspended by means of a pipe bracket clamped to the roof truss.

(iv) Each lighting point would be provided with means of isolation at truss level, by removal of either plug or fuses. This safety feature is necessary for maintenance, cleaning, re-lamping, etc.

Trunking has been found to be very economical and flexible for installation of high bay lighting, as the wiring for circuits other than that of lighting can be accommodated in the trunking. Circuits such as low power 440-volt 3-phase supplies for general services, 110-volt portable tools, hi-cycle tools, etc., can be installed quickly and easily, and space can be left in the trunking for possible future wiring.

Dealing first with the 1,000-watt mercury lighting installation, the fittings could be controlled in groups of six, each from a 30-amp triple pole H.R.C. switchfuse on a central control switchboard. With this arrangement, five switchfuse units could control the bay. Wiring from each switchfuse — comprising three 7/.029 V.I.R. cables—would be taken in the trunking to the various choke and condenser units which would be accommodated in sheet steel boxes and secured to the roof trusses. Each choke and condenser unit would be electrically protected by means of readily accessible 15-amp H.R.C. fuses in holders, the latter being provided with spring clips to resist vibration. Choke and condenser units mounted adjacent to the trunking would be connected with a short length of conduit through which circuit wiring could be looped-in from one unit to the next. From each unit a 2-core V.I.R.S.W.A. and S. cable would be taken to the associated lighting fitting, the cable being terminated at a connecting box in order that the final connection to the lamp could be made with 2-core T.R.S. cable run through the pipe bracket.

The 400-watt mercury lighting points could be switched in groups of nine, so that eleven switchfuse units would be required to control the bay. Wiring (7/.029) would be run in a similar manner to the 1,000-watt mercury installation, with the exception that conduit from the trunking would run to three lighting points per truss. Each lighting point would comprise choke and condenser assembly arranged in a mild steel box bolted to the reflector bracket. T.R.S. cable to the lamp would be connected to a fused socket outlet incorporated in the choke boxes. Three lighting points per truss would be arranged on the same phase, but each set of fittings per truss would be supplied from a different phase (A, B, C, A, B, C, etc.).

The 1,000-watt tungsten lighting points would be switched in groups of seven and eight alternately to suit the number of fittings installed. Each group would be controlled by means of a 30-amp T.P. and N. H.R.C. switchfuse. Wiring (7/.036) from the previously mentioned switchfuse would be enclosed in the trunking and looped-in to the lighting point positions, where it would terminate in a 5-amp socket outlet from which a 3-core T.R.S. flexible cable would be taken to the lighting fitting via the tubular bracket.

(4) Economics

In order to compare the economics of the three types of installation the following conditions were assumed:—

(i) Cost of electricity would be 1.1d. per unit.

(ii) The fact that the schemes utilising 400-watt mercury and the 1,000-watt

Table 1
Technical Details of Each Type of Lighting

		1000w M.V.	400w M.V.	1000w Tungsten Standard Fittings
•Actual KWH/HR		1.05	0.42	1.0
Lumens		50,000	14,400	17,800
Lamp Life (hours)		3,000	3,000	1,000
No. of Fittings		31	93	78
No. of Lamps required	Initially	31 × 1	93 × 1	78 × 1
	Replacements 1st 10 years Burning hours 27,000	31 × 8 i.e., 248	93 × 8 i.e., 744	78 × 26 i.e., 2,028
Total KW for bay		32.55	39.06	78.0
Units consumed (over 10 years)		32.55 × 2,700 × 10 i.e., 878,850	39.06 × 2,700 × 10 i.e., 1,054,620	78 × 2,700 × 10, i.e., 2,106,000

Burning hours 2,700 per annum.
•This includes choke losses for mercury lighting.

tungsten lamps would require higher kw. demand were disregarded from the point of view of adjustment to unit cost.

(iii) Costs were worked out over 10 years, based on 2,700 burning hours per annum. The figure of 2,700 burning hours per annum is based on day and night shift working over the whole year and has been substantiated by actual records kept of all burning hours during the past two years.

The results of the analysis are summarised in Tables 1-3. Table 1 gives technical details of each installation. Table 2 details costs of fittings, installation, lamp replacements, running costs, etc., and Table 3 summarises costs based on 10 years working.

It will be seen that for this high bay installation, where a good illumination is required at the working plane, the 1,000-watt mercury installation is the most economic and it was therefore chosen. It should be pointed out that the comparison has been made for *one bay only;* had a large number of bays been considered the saving would have been stepped up proportionally.

(5) Description of Installation Adopted

(5.1) Switchboard

Fig. 1 shows the Services Switchboard which is located at the centre of the bay. As the electricity supply is at 440-volt 3-phase 3-wire 50 cycles, the board is supplied accordingly; no neutral is necessary as the lighting is designed for 440-volt working. Incoming supply cable is connected to three-phase bus bars from which connections are taken to lighting circuit switchfuse units. As the lighting is fed from the main power network, switchfuse units must be provided with H.R.C. fuses. Each switch controls six 1,000-watt lamps and the circuit comprises a delta formation of two

Table 2

Detail Costs of Fittings, Installation, Lamp Replacements, Running Costs, etc.

		1000w M.V. 31 fittings	400w M.V. 93 fittings	1000w T. 78 standard fittings
Fitting Cost—less lamp. List less 20 per cent.		£ s. d. 10 17 7	£ s. d. 4 14 8	£ s. d. 3 16 10
Chokes/Choke	,, ,, ,,	11 0 10	5 2 5	
Condenser	,, ,, ,,	2 15 3	1 12 0	
	Total per fitting :	£24 13 8	£11 9 1	£3 16 10
Total Fittings Cost		£765 3 8	£1,065 4 9	£299 13 0
Lamp Cost	List less 22½ per cent. Per Lamp :	£6 4 0	£2 5 9	£0 13 6
Total cost of lamps	Initial Expenditure	£192 4 0	£212 14 9	£52 13 0
	Replacements 1st 10 yrs	£1,537 12 0	£1,701 18 0	£1,368 18 0
Total Units Cost 1.1d. per unit over 10 yrs.		£4,028 1 3	£4,833 13 6	£9,652 10 0
Installation Costs—*excluding* fittings control gear and lamps above		£753 15 6	£1,127 4 0	£1,158 18 6
Proportion of the cost of a 1000KVA transformer serving lighting (transformer valued at £1,370), and mains to supply lighting switchboard		£143 0 0	£178 10 0	£307 0 0
Extra involved in providing trunking to meet requirements for other services—not included in summary of costs		£100 0 0	£90 0 0	£80 0 0

(*a*) In the 1000w Mercury installation, more elaborate arrangements were necessary to support the lighting fittings the chokes and the condensers. The chokes and condensers, when assembled as complete units in substantial enclosures are so heavy that strong supporting plates must be provided on the roof trusses to which they can be secured.

(*b*) It was considered that part of the capital cost of the main power transformer should be allocated against each lighting scheme, owing to the fact that the power requirement is substantially altered in the different schemes. The complete installation actually consisted of eight bays similar to the 1000w M.V.D. scheme described.

lamps connected between each pair of lines, i.e. L_1-L_2, L_2-L_3, and L_1-L_3. Lighting circuit switchfuse units are fused at 20 amps.

From the rear of the switchboard a trunking, equipped with devices for securing the rising V.I.R. cables, is taken to meet up with a trunking running the whole length of the shop. This trunking is fixed to the angle tie bar near the eaves.

Trunking is provided to carry all lighting and service cables (such as hand lamp and hi-cycle supplies).

From the trunking, connections are taken in conduit to choke boxes, which are placed close to the trunking.

(5.2) Choke Box

Each lamp requires associate equipment in the form of two chokes and one power factor correction condenser. To localise and protect this equipment, the components are mounted on a 3-16th-in. mild steel plate (as a sub-assembly) prior to

being fitted into the ventilated container. A 3-16th-in. mild steel plate is clamped between the rafter and angle tie bar on the truss and the empty choke box is securely bolted to this plate. The choke and condenser sub-assembly is then bolted to the inside back of the box. Two H.R.C. fuses, of 15 amp rating, in holders, are arranged on the side of the box for the purpose of local protection and also as a means of isolation should it be necessary to carry out work on the lighting fitting. Fig. 2 shows a choke box *in situ* and Fig. 3 the choke box with lid removed.

(5.3) Lighting Fittings

The lighting fittings used have vitreous enamelled canopies and anodised aluminium reflectors. Heavy duty connecting pieces on top of the units are so constructed that the complete reflector can be easily removed without disturbing the circuit wiring.

Fig. 4 shows a fitting clamped to the tie bar of a roof truss. A ¾-in. gas mild

Table 3

Summary of Costs Based on 10 Years' Working (1)

A. CAPITAL ACCOUNT (A)	1,000w M.V.D. (31 off)	400w M.V.D. (93 off)	1,000w T (78 off)
	£ s. d.	£ s. d.	£ s. d.
Fittings	765 3 8	1,065 4 9	299 13 0
Installation	753 15 6	1,127 4 0	1,158 18 6
Transformer capacity to serve lighting and main cable	143 0 0	178 10 0	307 0 0
Total:	£1,661 19 2	£2,370 18 9	£1,765 11 6
B. RUNNING EXPENDITURE (B)			
Initial Lamps	192 4 0	212 14 9	52 13 0
Replacement Lamps	1,537 12 0	1,701 18 0	1,368 18 0
Power Costs	4,028 1 3	4,833 13 6	9,652 10 0
Replacement Costs and cleaning (2)	142 17 2	428 11 6	663 13 0
Total:	£5,900 14 5	£7,176 17 9	£11,737 14 0
Total depreciation (A)	1,661 19 2	2,370 18 9	1,765 11 6
Running Expenditure (B)	5,900 14 5	7,176 17 9	11,737 14 0
(A) + (B)	7,562 13 7	9,547 16 6	13,503 5 6
Some companies require that Interest on Capital be provided, say 5 per cent. per annum	831 0 0	1,185 0 0	882 10 0
Total, with interest on Capital	£8,393 13 7	£10,732 16 6	£14,385 15 6

(1) Capital cost assumed written off in this period.

(2) It should be noted that in a heavy engineering shop working on day and night shifts, lamp changing and the cleaning of both lamps and fittings are mainly carried out during weekends. This maintenance entails the services of a crane driver in addition to those of the electrical staff.

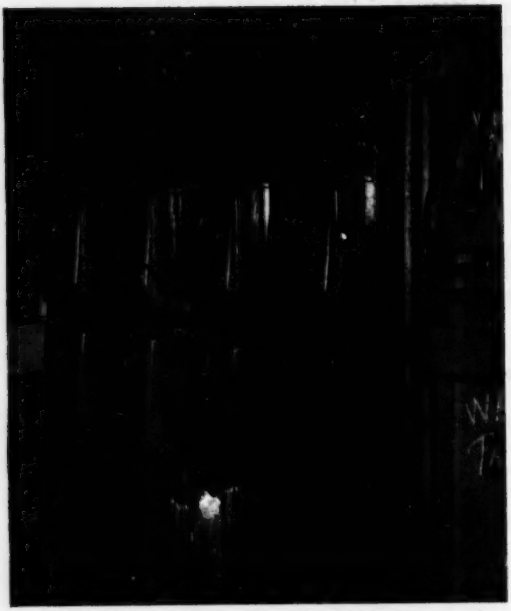
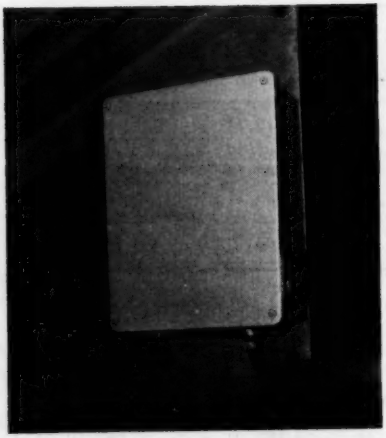
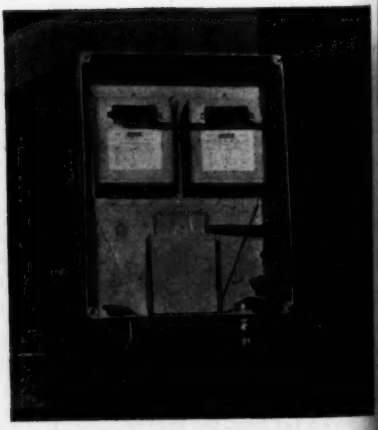


Fig. 1 (left). Services switchboard.

Fig. 2 (below, left). Choke box for 1000-watt M.V.D. unit.

Fig. 3 (below, right). Choke box with lid removed.





steel tube is bent to form a swan neck and two 1¼-in. x 5-16-in x 10-in. mild steel flats are welded edge-on to the end of the longer neck of the tube to serve as fixing plates. The bolts fixing the fitting to the tie bar are adapted for securing a mild steel strap carrying a standard 1-in. through box, and to this box is screwed a porcelain ceiling rose as a connector block for V.I.R. armoured cable from the choke box and the

2-core T.R.S. cable to the lamp. Cable is used from the lighting fitting to the choke box because it can be prepared on the shop floor and quickly clipped into position with the minimum of delay. The short end of the swan neck fitting is screwed 1-in. conduit thread to take the reflector. A bonding wire is connected between the fitting and the armouring on the V.I.R. armoured cable.

It will be observed that the choke box is not mounted close to the fitting. The reason is that the choke assembly is of considerable weight and if placed in any position other than that shown in Fig. 2 would cause the whole truss to vibrate excessively during the movement of overhead travelling cranes.

A point in favour of discharge lamps, where vibration may occur, is that they are free from filament troubles.

(5.4) Electrical Scheme

Fig. 5 shows the diagram of connections of a single lighting switchfuse circuit; one switch controls 6 1,000-watt lamps. The main advantage of the method of installation described is that lamp circuits can be looped-in from one choke box to the next; another advantage is that there is no difficulty in phasing-out each lamp to reduce the stroboscopic effect.

(6) Conclusions

On the basis of a 10-year period of running and the number of burning hours per annum at this factory, a very considerable saving has been made by adopting this 1,000-watt M.V.D. installation.

A final point which should be recorded is the fact that had 250-volt lighting been required it would have been necessary to install a 440-volt 3-phase 3-*wire*/440-volt 3-phase 4-*wire* 50-cycle transformer. This would have increased installation costs of the 400-watt mercury scheme by a further £180 and the tungsten by £320.

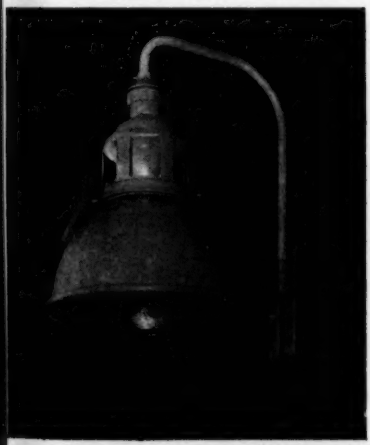


Fig. 4 (above) 1000-watt M.V.D. unit.

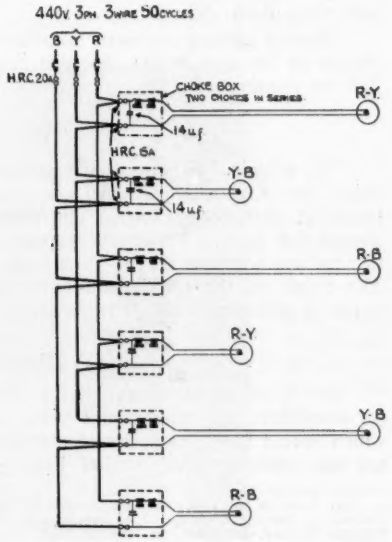


Fig. 5 (right). Diagram of connections. Each switch controls six 1000-watt M.V.D. lamps.

(4) A Blended Light Installation

By G. W. S. LEVEY *(Member)*

(1) Introduction

Blended light has been defined as "light which is a mixture of the radiations from two or more sources which have dissimilar spectral characteristics" (1). A mixture of mercury vapour discharge and incandescent filament sources were selected for lighting the Abbey Works of The Steel Company of Wales, as described in this paper.

Light sources with the highest intrinsic efficiency have the highest capital and replacement charges, so that the economic efficiency of an installation depends largely on local conditions such as natural lighting, working hours, cost of electricity and form of tariff.

The Abbey Works buildings have good natural lighting and as the predominance of a day and night power load leads to a high load factor the cost of electricity is comparatively low. These factors decrease the economic advantage enjoyed by blended light sources, but, as will be shown, the balance is still in their favour.

(2) The Works

The Abbey Works of The Steel Company of Wales takes its name from Margam Abbey, founded in 1147, which was associated with the iron industry. It is recorded that in A.D. 1253 the monks were engaged in mining iron at Cornelly, a few miles away from the new works. A steelworks was constructed at Port Talbot in 1901 followed by the erection of blast furnaces and ancillary plant at Margam Works, on an adjoining site, in 1916. Abbey Works for rolling strip has been built on a site of some 550 acres to the south of Margam Works. The first lighting contract was placed in 1948, a time when the supply of suitable materials and equipment was particularly difficult.

Blended lighting has been installed in the central engineering shop and the power station in Margam Works, but this description deals only with Abbey Works where half the lighting installation of 6,000 kw. is blended lighting.

(3) The Buildings

The principal buildings have bays about 100 ft. wide, the longest continuous bay being over 4,000 ft. long. All are equipped with overhead travelling cranes. Roof trusses at 40-ft. centres form a convenient support for walkways to which the lighting fittings are fixed. Transverse vertical glazing between the high and low sections of roof and windows on the outer walls provide good natural lighting (Figs. 1 and 2). The height of the roof trusses, and therefore the mounting height of the fittings, varies in different buildings from about 50 ft. to 80 ft.

(4) Illumination Values

The speed of movement of the product and the need for good general lighting for adjustment and maintenance of the complicated plant justify values of illumination which would have been considered uneconomical in older works. The operatives are also used to good natural lighting by day and therefore require the highest

Mr. Levey is with McLellan and Partners, Consulting Engineers. The manuscript of this paper was first received on January 22, 1954, and in revised form on March 15, 1954. The paper was presented at the Society's Summer Meeting, Southport, on May 20, 1954.

level of illumination which is economically possible at night. Design values in the blended light areas are:—

Slab Yards Melting Shop Raw Materials Bay Ingot Stripping Soaking Pits Brick Stores	6 lm./ft.^{2}
Mould Preparation Rolling Mills	12 lm./ft.^{2}
Slab Inspection and Conditioning Cold Strip Mills Sheet and Plate Finishing Machine and Roll Lathe Shops	20 lm./ft.^{2}

(5) General Considerations

Blended light is obtained by grouping separate mercury-discharge and tungsten filament lamps in the main bays and by using 500-watt MAT/V-type lamps in smaller areas.

Where the main shops are high, long and narrow as in the steelworks, capital and running costs can be kept down by reducing the number of lighting points to the minimum consistent with a uniform illumination over the working areas. By reducing the number of points, larger and more efficient lamps can be used to obtain a given result. Fewer points also make the provision of maintenance walkways an economical proposition; if smaller lamps are spread over a large area the cost of suitable walkways becomes prohibitive. In a steelworks the travelling cranes cannot be relied on as a scaffold for the maintenance of the lighting fittings, for when not in use for production they are either out of service for overhaul or required for the maintenance of other

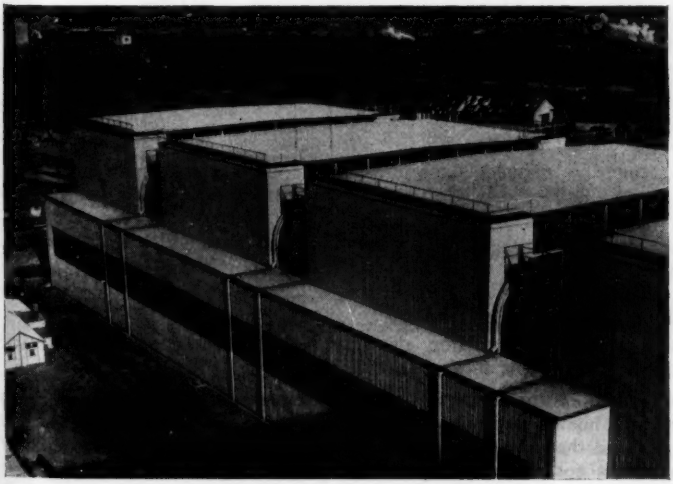


Fig. 1. Mould Preparation Bay showing roof construction.

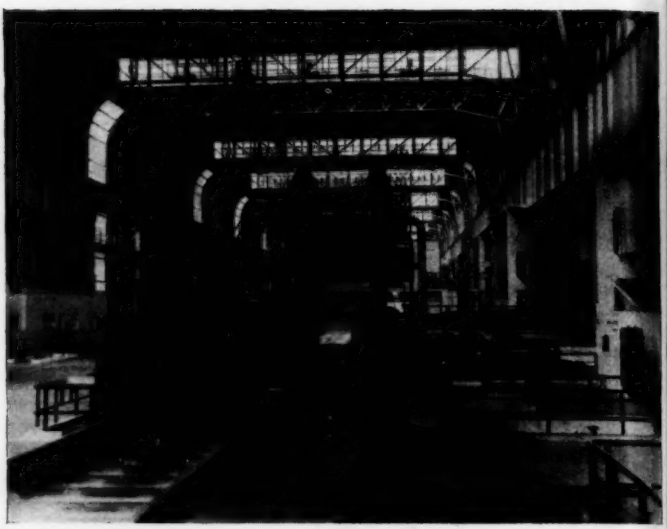


Fig. 2. Slabbing Mill.

plant. Walkways are provided for access to all high-level fittings in the main bays, and the maintenance programme is, therefore, not dependent on the use of cranes.

Groups of two 400-watt H.P.M.V. lamps with one 1,500-watt or one 1,000-watt G.L.S. filament lamp have been found satisfactory; the 1,000-watt mercury discharge lamps now becoming available will no doubt be even more efficient for this type of installation. The 2,500-watt mercury discharge lamp was found too large for the illumination required in narrow bays, where a single row of fittings is not suitable. A group output of about 57,000 lumens is the maximum required where the value of illumination does not exceed 6 lm./ft.^{2}

Blended lighting is better than either plain mercury discharge or tungsten filament lighting for the following reasons:—

(i) The predominant lines on the blue-violet and yellow-green wavelengths of the mercury discharge lamp compensate the weak emission at these wavelengths of the tungsten filament lamps and so improve the spectral composition of the light.

(ii) The tungsten filament lamp provides enough light to prevent a total blackout should the mercury arc be extinguished by a momentary drop in the supply voltage.

(iii) The efficiency is higher than that of a plain tungsten filament lamp installation. It was calculated that the higher cost of a blended-light installation would be balanced by the saving in running costs in rather less than five years.

(iv) The tungsten filament lamp also improves the overall power factor and reduces stroboscopic flicker.

It might be argued that the colour of light in a steelworks is immaterial, and better seeing conditions with higher efficiency would be obtained with plain mercury discharge lighting. It is accepted that the eye is able to focus more sharply when fewer colours are present, but this is not generally important in a steelworks where the visual task

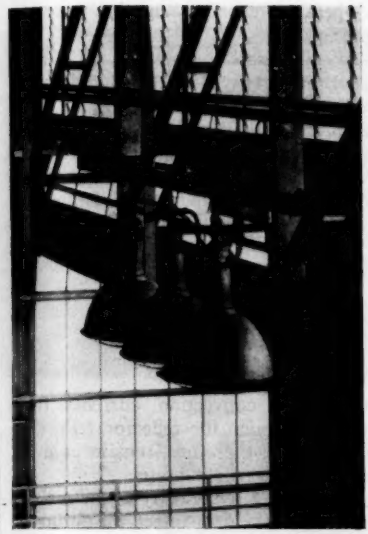
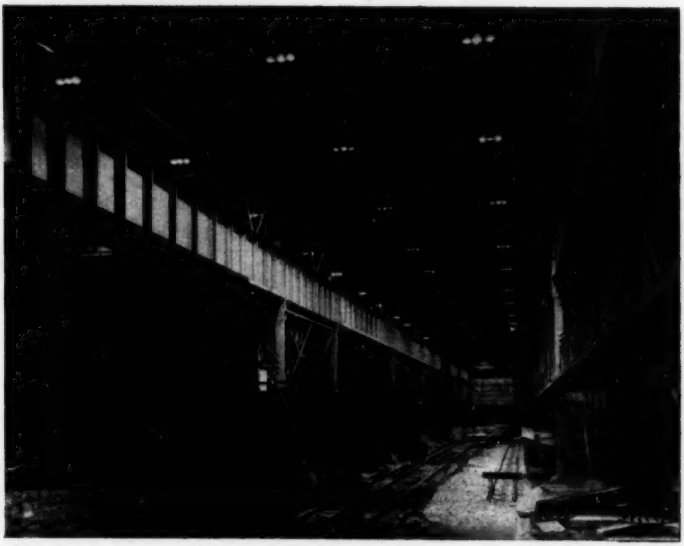


Fig. 3 (left). Group of enclosed lighting fittings showing also walkways and control gear.

Fig. 4 (below). View of Melting Shop in which enclosed fittings are used.



does not involve attention to fine detail. Arguments can be raised for plain mercury lighting but are outweighed by the risk of a total blackout for several minutes while the lamp cools down before the arc can restrike. The effect is worse than that of a total power failure because the power-driven plant would continue to run in the dark.

There are, of course, situations where a battery-operated secondary lighting system is desirable, but this is not peculiar to blended lighting.

It is difficult to assess the value of the improved spectral composition of blended light, but there is no doubt that it is better psychologically than tungsten filament lighting, and to most people it gives an impression of better illumination.

It is not considered necessary to raise the tungsten filament lamp output above that of the mercury discharge component, equal lumens giving a very satisfactory blend and an adequate measure of safety. Where suitable lamp sizes are available the mercury discharge output could be increased up to about 70 per cent. of the total.

(6) Lighting Fittings and Lamps

In view of the rapid depreciation of reflecting surfaces and lamps in a steelworks three types of fitting were considered :—

Type 1 : Fittings designed with open tops to allow convection currents to carry dust away from the reflecting surfaces;

Type 2 : Totally enclosed fittings;

Type 3 : Fittings which could be easily cleaned.

Type 1 was judged unsuitable because the violent convection currents from furnaces and hot metal disturb the controlled air flow through the reflector. Further, as shops have good natural lighting and the lamps would, therefore, remain cold for long periods, appreciable dust would be collected during daylight hours.

Type 2 has been chosen for the shops which are comparatively dirty as the melting shop and soaking pits, where a corrosive atmosphere is likely to affect the fitting or its accessories. Units of this type are shown in Figs. 3 and 4.

In other, cleaner areas, it was decided that maintenance costs would be materially reduced by designing a special fitting to house two 400-watt H.P.M.V. lamps and one 1,500 or 1,000-watt G.L.S. filament lamp. This single fitting is cantilevered from the walkway. The filament lamp is housed in a standard vitreous enamelled reflector in the centre, flanked by the two mercury lamps mounted horizontally with arc control coils and light gauge aluminium reflectors. The reflectors are secured by a simple spring controlled pin and can be easily removed for cleaning. The fitting is shown in Fig. 5 and an installation in the slabbing mill in Fig. 6.

The decision to use horizontal burning lamps and aluminium reflectors was based

Weathering Tests on Anodized Aluminium

Spec. No.	Position in Works	Condition after Exposure	Reflectivity* (per cent.)		
			(a)	(b)	(c)
1	Top of gas-holder	Dirty, no pitting	64	73	74
2	Over soaking pits	Dirty, no pitting	62	71	73
3	Over cogging mill	Dirty, no pitting	59	70	73
4	Office	Little dirt, no pitting	67	73	74
5	Pig casting (pouring)	Dirty, severe pitting	46	54	72
7	No. 1 blast-furnace platform	Dirty, slight pitting	48	60	71
8	No. 1 blast-furnace distributor	Dirty, severe pitting	33	34	73
9	Pig casting (strands)	Dirty, severe pitting	38	50	71
10	Melting shop, over furnace	Dirty, no pitting	62	68	69
11	Coke ovens (quenching)	Dirty, slight pitting	50	65	70
12	Over coke ovens	Very dirty, moderate pitting	12	28	67

* Original reflectivity approximately 75 per cent.

(a) Reflectivity in dirty condition after 4 months' exposure.
(b) Reflectivity after washing with soap and warm water.
(c) Reflectivity after washing and cleaning with "Luminisor."

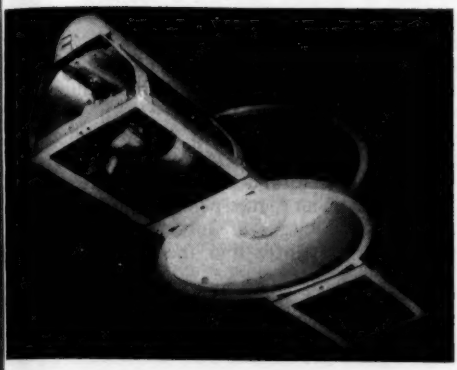
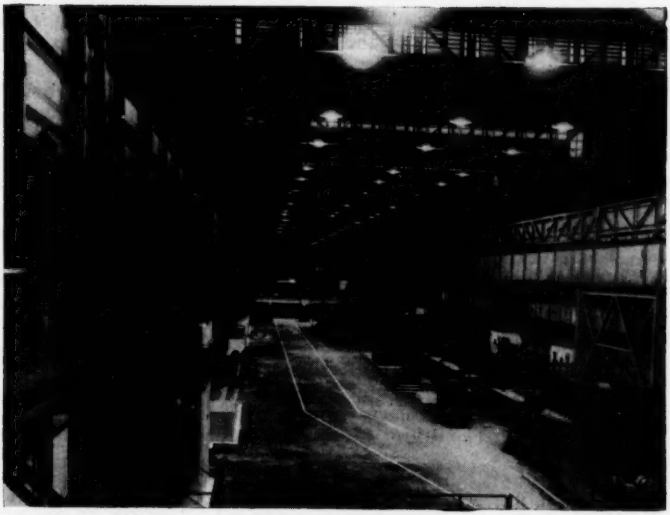


Fig. 5 (left). Special blended light fitting.

Fig. 6 (below). Slabbing Mill in which fitting shown in Fig. 5 is used.



on previous tests(2). It was found that the light output of a lamp burning vertically dropped 40 per cent. in 500 hours, whereas the horizontally mounted lamp output decreases by only 28 per cent.; this was largely due to the greater proportion of direct light obtainable from the horizontal lamp, the underside of which remained comparatively clean.

Experience with the effect of steelworks atmospheres on anodized aluminium was obtained by mounting specimens in the existing works(2). The results were as shown in the table.

It has since been established that the original estimate of three years' life for the exposed aluminium reflectors was conservative; it is likely to be over five years.

Where it has been desirable to extend blended lighting to lower and smaller buildings, 500-watt MAT/V lamps have been installed in deep-dome vitreous enamelled

reflectors. The lamps are costly, but this is simpler and more economical than blending the light from two lamps for so small an output.

Dispersive rather than concentrating vitreous enamelled reflectors have been installed to brighten the side walls by utilising the light which would be lost by inter-reflections in the concentrating type. The side sheeting was treated with an aluminium finish and has retained a comparatively good reflection factor.

The two main motor rooms are of similar construction to the main buildings, but are air conditioned; walls and ceiling are both painted. Open-top moulded glass reflectors have been used for these rooms and are mounted in pairs with one 400-watt H.P.M.V. and a 1,000-watt G.L.S. filament lamp per group. These are attached to the roof trusses at 40-ft. centres. Walkways are not provided because the rate of depreciation is much less than in the works and the crane is usually available for maintenance.

(7) Wiring and Control

To avoid 415 volts on the fittings, each group of lamps is connected between one phase and neutral of the three-phase supply; groups are then balanced over the three phases. The tungsten filament lamp damps out any stroboscopic effects which might be expected with single phase units mounted at about 40-ft. centres.

The chokes and an isolating switch for each group of lamps are housed in dust-tight enclosures adjacent to the fittings. Power factor correction is by capacitors connected across phases at the main fuseboards. This reduces the cost below that of individual capacitors connected between phase and neutral at each lamp.

The cost of final subcircuit wiring was kept to a minimum by mounting all main and submain fuseboards and contactors at crane-rail level and by connecting the mineral insulated copper-covered cables as an earthed-concentric system. This system reduced the wiring costs by about 25 per cent. and has the further advantage of reducing the voltage drop. The resistance of the sheath of a single core .0045 sq. in. cable, for instance, is less than one-third that of the core.

Each contactor controls 12 groups of lamps. Pushbuttons are at floor level. Where the illumination is 20 lm./ft.^{2} alternate fittings are controlled by different contactors so that the load can be reduced when not required for inspection.

Acknowledgments

The paper is published by permission of McLellan and Partners, the Consulting Engineers.

Acknowledgment is made to The Steel Company of Wales, The Benjamin Electric, Ltd., and The British Thomson-Houston Co., Ltd., for the loan of photographs.

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(1) Anderson, S., Trans. Illum. Eng. Soc. (London), **18,** 15 (1953).
(2) Levey, G. W. Journal of the Iron and Steel Institute, **165,** 93 (1950).

Discussion

MR. J. S. MCCULLOCH: This series of short papers is a most interesting innovation. Here we have four engineers each of whom was required to select a lighting scheme for a particular factory, and each has chosen a different light source It is a great significance that the lighting industry can offer this variety; it is a sign of the virility of the industry. The Papers Committee are to be congratulated on obtaining details of four such diverse schemes, each of which nonetheless contains the same fundamentals for comparison, namely, three-shift working, similar cost of electricity and reasonable levels of illumination for the job to be done.

I agree with the decisions of two of the authors—Mr. Clark's choice of hot cathode for his factory and Mr. Levey's choice of blended light for his. I suggest, however,

that Mr. Howe has deceived himself on the economics of his choice—the cold cathode installation—and that Mr. Jones has allowed the undoubted economic advantage of his mercury vapour lighting to outweigh its disadvantages.

Mr. Clark arrives at his annual charges on capital for his hot cathode scheme in a somewhat involved manner and he seems to ignore interest. With present interest rates of 9 per cent., the annual charge to write off the difference of £1,137 between the two schemes is £102, which is more than his figure of £76. It is not sufficient, however, to alter the economic balance of his scheme. In my opinion, both from the economic aspect and from the aspect of application to his particular factory, I think he was right to install the hot cathode scheme.

He gives in his paper, almost as an aside, a rather provoking thought. Is the improvement in production resulting from the improved lighting maintained after lighting engineers have gone? I would like to know if anyone has had any experience of this.

I do not agree with the basis of Mr. Howe's calculations for his cold cathode scheme. The allowance of 4,200 hours per annum for the operating life of lamps in a north light factory is very high. Factories with north lighting have a good daylight factor and I am sure the hours should not be more than 3,500.

Secondly, I suggest his figure of 1d. a unit for electricity is too low with coal at its present price. I agree with the more reasonable figure of Mr. Clark and Mr. Jones of 1.1d. per unit.

Thirdly, I see no reason why Mr. Howe should not accept the normal average life of 5,000 hours for hot cathode lamps. We have already heard Mr. Clark say that it has proved to be satisfactory and I too have found 5,000 hours reasonably correct.

Fourthly, Mr. Howe gives the consumption of an 80-watt hot cathode lamp and choke as 100 watts: why has he not accepted the normal figure of 90 watts?

Working out his calculations A and B again, and altering only two of the values on which I do not agree with him, i.e., using 5,000 hours life for hot cathode lamps and 180 watts consumption for the twin tube fittings, the cold cathode installation becomes nearly £7 dearer than the hot cathode. That shows how careful one must be in making economic comparisons of hot and cold cathode installations. I have just heard that the cold cathode lamp life has been increased from 15,000 hours to 30,000 hours; if so, this will again alter the comparison.

I suggest Mr. Howe should not try to justify his cold cathode scheme on economic ground alone. Cold cathode lighting has advantages which cannot be evaluated monetarily. One is the good psychological effect of a continuous line of lamps compared with what one might call a broken line of hot cathode lamps with the odd lamp or two burnt out. In trying to justify his cold cathode installation I think the author should concentrate on advantages other than those of economics. I have considered installing cold cathode lighting in many industrial premises but I have never been able to justify its installation on economic grounds alone.

It is probable that Mr. Jones's mercury vapour lighting is the most economic method of lighting high bay engineering shops, but this type of lighting has disadvantages and, I would go so far as to say, is dangerous in industrial premises. I personally would not like to work continually under mercury vapour light and I do not see why I should ask other people to work under artificial light so lacking in colour rendering. The dangers of using the mercury light source alone in factories is mentioned in Mr. Levey's paper. A momentary drop in voltage of the supply can extinguish the mercury vapour lamps, but the voltage drop may not be sufficient to cause machinery to drop out on low volts. Consequently, while the lamps are cooling down before re-striking, the workshop is in darkness with cranes and machinery still running. Blended light, combining mercury vapour and tungsten lamps, is much to be preferred for industrial use though it is not as economic.

My final comment on Mr. Jones's paper is to say how pleased I am to hear a

paper read before this Society containing much information on the wiring installation and switchgear. The lighting engineer is apt to forget about that part of the lighting scheme.

Mr. Levey's choice of blended light is a good one and, as I have said when criticising Mr. Jones's installation, I think it is the best type of lighting for high bay shops.

To sum up, my opinion is that for high bay engineering shops covering large areas where the height to the eaves is above, say, 25 ft., blended light satisfies the functional, economic and safety requirements for a good lighting installation. For other shops with lower roofs, the modern hot cathode fluorescent lighting supplies the best economic answer, though cold cathode lighting has some psychological advantages

Finally, it should be remembered that these four papers are comparing installations in factories working those shifts where the lamps operate for at least 3,000 hours per annum. Our old friend, the tungsten lamp, can often beat the new light sources on economic grounds when installations are used during only one shift a day, say, 500 hours a year.

MR. A. LIPPESTAD (Norway): It has been very interesting to hear these four papers. I have worked on these problems for some years myself from the consumer's point of view.

I am engaged, among other things, with the industrial lighting installations for Norway's largest industrial undertaking, the Norsk Hydro-Elektrisk Kvælstofaktieselskab.

In our four large factories we consume about 15,000,000 kilowatt hours annually for lighting alone. In our main production of fertiliser we use 3,500 million kwh. a year at a cost of about 1d. per kwh. Our consumption of electricity for purposes of lighting thus amounts to an annual value of 1,000,000 Norwegian crowns, about £50,000. A sum like this should be treated with respect and it should be the duty of an electrical engineer to see that the lighting installations are as good and as efficient as possible.

When I began, some years ago, a systematic survey of the lighting installations in our factories, I found that the flux received at work level varied from 16 to 40 per cent. of the total light output, the actual value depending on the mounting height which varied from 6-12 metres. A closer investigation showed that the efficiency of utilisation of the light output was far lower than we technical people are used to as a rule. Measurements made for us by the Technical University in Copenhagen of the efficiency of the various types of fittings gave results varying from 42 per cent. for large, deep reflectors to 74 per cent. for tubular fluorescent lamp fittings of the industrial reflector type. As all these various types of fittings are used in our factories, the most we could reckon with was an average efficiency of 60 per cent, i.e., a loss of light and thus a loss of energy in our lighting fittings of about 40 per cent. This means for us an annual loss of 6,000,000 kwh. valued at £25,000 per year.

On this basis I have worked on the problem of obtaining fittings with higher efficiency as, in my opinion, it should be possible to cut this loss by half. We have a type of deep reflector for blended light (mercury+tungsten lamps) which is still supplied by manufacturers of light fittings. The efficiency of these is sometimes less than 50 per cent. This type resembles a pail and has the ability of the pail to retain its contents. The big special blended light fitting shown by Mr. Levey has also been introduced into Norway but is so expensive that its higher efficiency in no way compensates for its high cost. The cost in Norway for such a fitting is about £55. Design of a new fitting of high efficiency but reasonable cost is urgently needed.

The ordinary fittings for use with hot cathode fluorescent lamps are narrow basins from which it is difficult for the light to emerge. These have efficiencies ranging

from 67 per cent. to 74 per cent. As a preliminary result of my work for more efficient fittings—which must also have a good distribution of light and diffuse reflection without mirroring—I have decided on a fitting for two 80-watt lamps which has given a really good result compared with the above-mentioned types. This fitting is very open, with the tubes pushed down so that the space between the tubes and the reflector is equal ot the diameter of the tubes. There is also good space between the tubes. The fitting is intended to be installed at a high level and not lower than seven metres above the floor. It is consequently not necessary for the fitting to have deep side walls.

The efficiency of this fitting has been measured at the photometric laboratory at the Royal Technical University in Stockholm and the result was equal to 86 per cent. It is also interesting to note that the measurements for this fitting give the same efficiency results regardless of whether there are one or two lamps in the fitting. This is probably due to the big space between the tubes and the size of the fitting as a whole—particularly its considerable width. Previous measurements we have made with the ordinary narrow fittings having little space between the lamps showed that the efficiency of the fitting with our lamp is higher than when two lamps are used. The same applies to a three lamp fitting. I have fitted 100 of these new type three lamp fittings in a workshop having a floor area of 2,000 square metres with the fittings mounted at a height of 12 metres. After operating for 500 hours, the average illumination at one metre above the floor was 200 lux, corresponding to 55 per cent. of the light output from the lamps. As this is twice the efficiency previously obtained, I consider the result a very good one and have recommended this fitting for further installation. Based on the requirements for a certain lighting level, I reckon that we save at least £250 per year in the cost of electricity in this one workshop alone.

A corresponding improvement over the entire organisation where I am employed would mean an annual saving of £10,000-£15,000. This is perhaps considered as small money nowadays, but why not save it if we can?

It is such things as these which have prompted me, as a consumer, to propose that the C.I.E. makes the subject of "Economic and Efficiency Problems in Lighting" one of the main points on its general programme.

As the improved fittings use mainly standard components, apart from the reflector, the fittings are only slightly more expensive than the ordinary fittings of lower efficiency—and the total installation costs for the workshop mentioned have only been slightly more than usual.

The total costs for the installation in this instance, including wiring, fittings and everything else come to about 43,000 shillings, which equals 22 shillings per m^2 illuminated floor area. Of this the fittings themselves account for 19,000 shillings or about 10 shillings per m^2. This corresponds exactly with our average installation costs for new, good lighting installations.

As regards the costs, it must be remembered that where fittings of higher efficiency are installed, fewer fittings are necessary provided the mounting height is such that the uniformity of illumination is still satisfactory. Thus the total capital costs will not be more, even though the fittings cost more; the running expenses will be less

At the same time as we demand good economy we also require illumination of good quality at our factories. We do not sacrifice good lighting distribution, diffusion, and avoidance of glare, etc., to economy. We must have a good "lighting-climate" in our factories.

I would also mention that the above information is all based on the assumption that the fittings are clean and the lamps clean and efficient. In our factories this is a matter which is given regular attention.

I hope that I have managed to give you an impression of some of the aspects

of lighting systems which specially interest us as consumers. In addition, of course, the economics of light sources is also of very great interest, but this is too complicated a matter to go into here.

MR. A. N. IRENS: I do think that Mr. Clark is a very brave man for saying what he did on one particular aspect of this problem. Unless I misheard him, he said that after all this improved lighting he did not think that it made a very big difference to production. Well, I do not know if there are many here who agree with him, but I find it very hard to do so myself. Although I do not know anything about this particular industry, nevertheless I am convinced that in industry as a whole we have everything to gain by pressing the cause of better lighting in all our factories.

As Dr. Aldington has pointed out, we spend vast amounts on heating our factories, and very little, by comparison, in lighting them. The plant load factor is very bad for a really good heating installation which copes with the coldest possible weather, whereas the load factor on a lighting installation which gives good-quality illumination is very high indeed.

We all know that with better lighting conditions the operatives call for the light earlier in the afternoon and keep it on longer in the morning; the load factor is therefore higher and the overall cost per unit should be a lot less for a high illumination installation that it would be for one of low illumination. From the supply authorities' point of view that means that high lighting levels are something to be encouraged. I am glad to see that most of our Area Boards and other supply authorities are paying a lot of attention to this subject of lighting. There are a number of delegates here from the Area Boards, and it is to their interest and in the interest of the consumers as a whole to press hard for improved standards of lighting.

A factor on which I would have liked to have been able to give you more detailed information is the percentage of the total wage bill which is spent on lighting in the average industry. This is not possible at the moment, but in general for quite a number of industries, the cost of really good, modern lighting worked out at about half or perhaps one per cent. of the wage bill at the very most. I think there would be few people who would not say that one would get at least one per cent. better output from the operatives. I think this matter of relating the cost of lighting to the wage bill is useful and powerful when discussing any industrial lighting scheme with the management.

I should mention one other factor which I think illustrates to some extent the benefits which can be obtained from really adequate lighting. I had the opportunity of looking at quite a few American factories last year. I am not saying that necessarily everything they do is better than we do, but one thing that did impress me was that the kilowatt hours consumed per worker in the United States is very much higher than it is here. I looked round for reasons and, quite honestly, as far as mechanisation goes I did not see much reason for this increased consumption except, perhaps, that certain sections of the community over here insist on one man per machine, whereas in the States they are more likely to allow one man to look after three or four machines. That comes into it, but I am certain that the main reason for this increased use of electric power over there is their lighting. As you all know, for an ordinary factory, they plan for illuminations of 30, 40 or 50 lm./ft.^{2}. Compare that with our figures: we think we are really getting somewhere with 15 or 20 lm./ft.^{2}. Our American friends do not spend money without a reason; they analyse everything and look at costs very carefully. They do not put in 50 lm./ft.^{2} installations for fun. I suggest they do it because they get better production and they have got past the

stage which, perhaps, we are sometimes in where operatives say: "It was good enough for my dad, it is good enough for me." We have got to go further than that.

MR. J. S. HEMMONS: Mr. Howe has, I feel, been scrupulously fair in his comparisons. He has been at pains to emphasise that the points mentioned in favour of cold cathode lighting apply only to this one installation. I think his calculations were made in about mid-1951, and at that time cold cathode beat hot cathode by a very short "economic head," as Mr. Howe's figures show. Now, if we assume an average life for hot cathode lamps of 5,000 hours as opposed to his figure of 4,200 hours, the cost of lamp replacement for this arbitrary unit becomes £25.4, and the total cost for the 10-lamp unit becomes £111.9, as compared with £114.6 for cold cathode. That was three years ago; since then great improvements have been made in hot cathode fluorescent lamps both in regard to average life and uniformity—this is a point which has not been mentioned this afternoon, but, obviously, uniformity is very important. We do not want a wide coefficient of variation in the life of the batch which is being used.

Bulk replacement has been discussed for a long time, and with rising labour costs it is becoming increasingly more desirable. Now perhaps, for the first time, it has become a practical and an economic proposition. All four of the speakers have sought to justify their own particular system of lighting, but at the same time I feel we shall be able to learn much if we try to draw the common points of interest from all four papers; in particular, this important question of bulk replacement obviously concerns them. Mr. Levey was talking about the uneconomically long life of his mercury lamps, and any system whereby bulk replacement can be economically introduced must be considered most carefully.

Mr. Howe stated that when his installation was being designed instant start gear was in an early stage of development, and at that time the saving on starter switches was insufficient to justify the higher capital cost of instant start control gear. I think the position now is that the production of combined instant start units at the same cost as the component parts of the switch start circuit is gradually becoming a practical proposition, and the use of these combined units will remove the £10 starter switch replacement figure and provide a generally more attractive installation.

MR. L. C. RETTIG: I have listened with interest to the four papers and would comment first on the paper given by Mr. Clark. In common with most things which are considered when a new installation is being put forward, there are a number of factors which in the broad sense of trade would be termed "hidden exports." Here they are "hidden benefits" and one of those which has to be taken into consideration is the reduction of physical fatigue under higher values of illumination.

It has been proved, I think, quite conclusively that eyestrain is responsible for physical fatigue and not for eye defects, as we thought originally, and also that physical fatigue is evident even under mechanical processes in the increasing number of faults and errors at the end of a day's work.

Mr. Clark has, rightly, also referred to the increased age of workers and the fatigue which they experience by continuing in their jobs when perhaps they should have retired. This is another justification for higher values of illumination, and a factor which can rank with proper seating, minimising body movements, and other safeguards now commonly accepted as necessary to maximum output.

Also, to get better production figures and to reduce errors still further it should be recognised that to get any appreciable alteration it is necessary to increase the illumination logarithmically: in other words, the transitional stages of illumination have to go up, not in a straight line scale but in a log. scale if the benefits are to be noticeable.

I must question the accuracy of Mr Howe's calculations since on the experience

of isolated tests he reduces the probable life of the lamps in his selected installation, the cold cathode, by 6 per cent. and the alternative hot cathode by 16 per cent. As an engineer, I feel that there is a serious disadvantage with cold cathode in lumens per watt at the end of life. Taking into account the extremely long life of a cold cathode lamp, it is reasonable to assume that the differential of replacement will be such that the low value of illumination will pertain over the whole installation at the end of, say, the third year whereas with the intermediate replacement of hot cathode lamps there would be a sort of differential throughout the works which would keep up a better average value of illumination.

I was very interested in the papers given by both Mr. Jones and Mr Levey but I see no consideration has been given in these very high narrow bay installations to side lighting mounted underneath the crane rails. This type of installation often proves to be an economical proposition both from the point of view of installed wattage and also in maintenance which can often be carried out from the floor level. It must be agreed that a reduction in the number of catwalks represents a considerable capital saving, apart from the fact that it would appear that an increase in the illumination on vertical surfaces would be a desirable feature of the installation reviewed.

MR. S. ANDERSON: I am not sure whether the authors set out with the intention of "debunking" some of the lighting engineers' pet theories and arguments, but I do feel that they have done so, whether intentionally or not. I think, perhaps, that is good for those of us who are practising lighting engineers, because it presents us with a challenge.

At the same time I have felt that while they may have upset our pet argument in favour of one type of lighting or another, they have not given us much in the way of alternatives. In their replies to the discussion, I am wondering whether they could elaborate a little on their reasons other than the economic one, for favouring the lighting installations they have described.

I was interested to hear Mr. Clark's point of view that when one is concerned with machines which operate at a fixed speed—determined by the prime mover—the quality and the intensity of the lighting can make little difference to production. Obviously, that is correct during the time the machine is running happily, but I have heard on a good many occasions, in the textile industry among others, that the time when good lighting pays dividends is when there is a stoppage. The faults are found more easily and can be rectified more quickly. Surely, if the time lost in stoppages can be reduced, the overall output of the machine and of the factory is increased.

It seemed to me that the type of work in the Abbey Works was not dissimilar to that in Renfrew Works. I would be interested to hear further from the respective authors their reasons for choosing a blended light system for the one factory and the plain mercury system for the other. There is some economic advantage in favour of the plain mercury system in the Renfrew Works, and if the major advantage of the blended system is that total darkness is avoided when a voltage drop occurs which causes the high-pressure mercury lamps to go out, surely a much smaller proportion of tungsten lighting than that used by Mr. Levey would be sufficient for safety purposes. I think everyone will admit that the higher the proportion of tungsten to mercury, the higher is the operating cost and, of course, the higher the number of lamps to be replaced at 1,000-hour intervals.

We have heard of the disadvantage of the poor-colour quality of a plain mercury installation, but we did not hear any criticism of that nature from Mr. Jones, and I would be interested to know whether he has in fact found it to be any disadvantage in heavy steel work. I am under the impression that where the work-people are largely, or entirely, male, the psychological effect of the poorer colour is not a major

factor, and I think Mr. Jones's paper has pointed out quite clearly the very considerable economy which can be obtained by using these high-wattage plain mercury lamps.

I was also interested in the remarks concerning the necessity for providing easy access to these high-mounted lamps and fittings for maintenance purposes. It occurred to me that when planning a new factory with high mounting positions, it might well be more economical to provide a light, travelling platform running on rails above the crane rails in each bay rather than to provide fixed catwalks. I would have thought that a travelling platform allowing maintenance men to get to the fittings above the cranes would be much cheaper than the provision of fixed catwalks, which must involve a great deal more steelwork.

I think everyone concerned with lamp manufacture will be interested in the theory that a lamp with a short life has considerable advantages over one with a long life, and I have no doubt that the lamp manufacturers here will go away and take that very much to heart!

MISS I. JACKSON: I recently visited a very large steel works where many modern conveniences such as baths were provided for the workers. In the moulding bay there was sand and dust all over the place, including the lighting fittings; no dust extractor appeared to be installed. If dirt is allowed to collect on fittings in high bay installations it is obvious that the installation will not for long remain a good one; it is not the fault of the lamps if the illumination falls simply because the fittings are not clean.

I would suggest that if new lighting is to be installed in a works the reasons for the new lighting and the benefits to be derived from it should be explained to the workers; perhaps the type of fittings to be used might be put on display. It is possible that this may lead to some constructive suggestions and to better results from the new lighting than would be obtained without inviting the co-operation of the workers.

MR. S. T. CLARK (in reply): In reply to Mr. McCulloch, I agree that some account must be taken of interest on capital; 9 per cent., however, seems very high. On this vexed question of improvement of production by virtue of better lighting, my opinion still is that, taking away all other factors, once operatives have become accustomed to the improved lighting they fall back to a normal level of production. I entirely agree with his final paragraph regarding our old friend, the tungsten lamp.

I agree with Mr. Irens that we must aim at better lighting but, to quote our own experience, we were unfortunate from a lighting engineer's point of view that we put into operation our incentive schemes before our improved lighting. It would be interesting to see the effect on production of withdrawing the incentive schemes; I am sure that better lighting would do little to compensate for their loss.

Mr. Hemmons raised the question of bulk replacement of lamps. This has advantages where fittings are difficult to reach. In our experience, as most of our lamps are only 8 or 9 ft. above floor level, it is cheaper to replace each lamp as it fails. We estimate that our own night electrician can change a fluorescent lamp in about 20 minutes, the only cost involved being wages.

I agree that good lighting is a factor which reduces physical fatigue, although to quote an exception, a loom tuner has complained that, since we improved our lighting, he suffers greater physical fatigue than before, because he has constantly to lie on his back and work up-hill, looking into the light source. Physical fatigue is, to quite an extent, overcome by morning and afternoon tea breaks.

In reply to Mr. Anderson, there is an unknown value in providing better working conditions. Some schemes, such as sports grounds, canteens, etc., have no economic value at all, whilst others have only part economic value. Lighting schemes, unless

they fulfil the need for decoration, stand or fall on their economic value alone. In other words, if they do not save money they will most probably be vetoed.

When machines have a fixed speed, e.g., looms, a reduction in time taken to correct faults is a definite saving. On a loom working at 80 per cent. efficiency the balance of 20 per cent. covers fault correction, plus all deliberate stoppages mentioned above. Time taken in fault correction is dependent on quality of material being used. Good lighting will reduce this time, but 25 per cent. saving in this way may only mean 2.5 per cent. of the total efficiency.

It is noticeable that an operative with a normal 80 per cent. efficiency will, before Christmas, Easter, Whitsuntide, and the annual holiday, improve this machine efficiency by as much as 10 per cent., up to 90 per cent., and, after these holidays the efficiency may fall to 68-75 per cent.

I agree with Miss Jackson about inviting suggestions from employees, but the difficulty is that what satisfies one employee may not satisfy another. We have found this quite a problem, not so much in lighting as in other improvements, e.g., ventilation and heating.

MR. HOWE (in reply): It would appear that some people do not agree with me; this is not unexpected.

I have stressed that the facts and figures which I have quoted are confined to a particular installation, and that those dealing with local conditions were not necessarily intended to be generally applicable. Thus, although Mr. McCulloch does not accept the figure of 4,200 hours per annum as a reasonable operating period, I am compelled to use it because carefully kept statistics at a sister factory show that this is, indeed, the correct figure for that particular installation. Similarly, I cannot use the price per unit of 1.1d., as suggested by Mr. McCulloch, purely because the data supplied to us showed the price to be precisely 1d.

Mr. McCulloch states that there are certain merits of cold cathode lighting which cannot be expressed in purely monetary values. With this I fully agree. But when he suggests that I should have concentrated on these other advantages and not on economics, I must point out that the whole subject of this discussion is the *economics* of lighting installations, and this aspect must accordingly receive the greater attention on this occasion.

The figure of 5,000 hours is, I agree, generally quoted as the life of a hot cathode lamp, and all lighting manufacturers will give that figure to-day. At the time of this installation not all the makers made this claim. We reserved the right to take actual figures from other projects over which we have control and, in the light of these, 4,200 appeared to be a realistic figure and one which I still hold to be fair. It is, without disparaging in any way the claims of the makers, the right of a buyer to check claims in the light of personal experience and to judge accordingly.

As I have stated previously, the figures were intended to provide conservative estimates, and it may equally be argued that the figure of 14,000 hours claimed for cold cathode lamps is somewhat low. I have always felt that if one tells a client that a service will cost £100 and at the end of the year one can say "Well, in fact it cost only £95," there is never a complaint. If the converse applies, then criticism is due and is seldom lacking.

The remarks of Mr. Hemmons on the improvements in hot cathode lighting are very true and are doubtless confirmed by the experience of many of us here. However, I think it only fair to say that there have been parallel improvements in cold cathode lighting and that the figure of 30,000 hours is now mentioned as the life of a cold cathode lamp. I agree, too, with Mr. Hemmons that my figures show that cold cathode lighting beat hot cathode "by a very short economic head," but I have stressed that

when a degree of suitability is established, parity or even near parity of economics is sufficient to justify selection.

I have previously stated my belief that statistics should be presented in as simple a form as possible and that where errors are balanced and are not cumulative, then they are justified. It was for these reasons that I chose the round figures of 200 watts and 400 watts as the consumption figures of the respective units although I agree that more exact figures would be 180-185 and 390.

We feel that this is a satisfactory installation. It has justified its cost and meets with the requirements of the people who had to pay for it.

I would like to say in conclusion that I was very interested in Miss Jackson's pertinent remarks on the cleanliness of industrial lighting fittings.

MR. JONES (in reply): With reference to the remarks made about working under mercury lighting as compared with working under, say, tungsten lighting, my opinion is that where the illumination values are low, tungsten lighting is to be preferred. If, however, the illumination value is of the order of 15-20 lm./ft.^{2}, as in the installation described in the paper, the choice of mercury lighting does not result in any discomfort.

Some speakers have suggested that the use of plain mercury lamps may result in danger owing to the time lag in restriking following a drop in voltage. This is something the writer has never experienced in the Renfrew works. If this should happen in the future, however, we are safeguarded by the fact that tungsten pilot lighting is installed with all mercury installations (principally for watchmen on their rounds), and even though it is of relatively low intensity, it would provide sufficient movement lighting while the M.V.D. lamps were restarting.

A check is taken of the hours lamps are in service, and after a predetermined period old lamps are replaced. This is a policy which is rigidly adhered to, as it is uneconomic to operate lamps much beyond their specified life, mainly due, of course, to the reduction in light output.

It is preferable that all lighting should be reached from the platforms of our overhead travelling cranes to facilitate cleaning of fittings and lamp replacements. In certain installations fittings have been dropped 9 ft. in order that they could be serviced from the crane platforms.

As for cleaning fittings, a permanent night-shift is employed for this purpose; the maximum level of illumination can thereby be maintained.

The economics of the lamp was the main reason for installing 1-kw. mercury lighting for high bay mounting. Colour discrimination is not really important in large industrial shops handling crane construction, 100-ton boiler drums and special vessels. Economically, this type of lighting has proved best for this particular application, and its use has not resulted in discomfort to personnel.

MR. G. W. S. LEVEY (in reply): I do not understand Mr. Lippestad's remarks about the high cost of the special fittings. The cost in Norway is apparently higher than in this country, but the relative cost of different types of fitting should be the same. The fitting shown cannot be compared with an enclosure housing three lamps without individual optical control.

Several speakers have mentioned the effect of good lighting in increasing production. Good lighting no doubt does this, but, what is even more important, it helps to prevent accidents, which is an indirect but none the less desirable way of increasing production.

Mr. Rettig suggests lighting from crane girders. This side lighting would not be satisfactory because shadows would be thrown across the bays by mill stands and

other high equipment. Good illumination on the vertical plane is not necessary in a steel mill, and it would be a hazardous job maintaining the fittings from floor level.

I agree with Mr. Anderson that a smaller proportion of tungsten lighting would be satisfactory—I suggest 30 per cent. in the paper—but the proportions are largely controlled by the lumen output required per fitting and the size of lamps available. The 1,000-watt mercury discharge lamp was not on the market when the Abbey installation was designed. Two 400-watt H.P.M.V. and a 1,000- or 1,500-watt G.L.S. lamp gave the "group" output required. Mr. Anderson will no doubt agree that a 125-watt and two 400-watt H.P.M.V. lamps with a 750-watt G.L.S. lamp would be relatively uneconomical.

The space between cranes and the underside of roof trusses would not normally allow a travelling structure. I am sure the cost of a gantry to span 100 ft., with its rails and supporting steelwork, would cost more than walkways.

Regarding lamp life, I suggested that lamp manufacturers should aim to increase the efficiency and lower the cost rather than to give a longer life. I also suggested that it would be a good idea to incorporate a cut-out device to end the life of mercury discharge lamps at the appropriate time.

Where maintenance is not too good, a lamp failure does at least mean a clean lamp, and most fittings require attention after operating for 3,000 hours. It would, of course, be advantageous to increase the life of tungsten filament lamps to 3,000 hours.

I agree entirely with Miss Jackson's remarks about keeping fittings clean; many works would be much brighter if the people concerned held the same views.

Additions to the List of Members

The following applicants have been duly elected by the Council to membership in the Society and their names have been added to the list of members:—

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